U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-285 480

Development Document for Effluent Limitations Guidelines for the Pesticide Chemicals Manufacturing, Point Source Category

U.S. Environmental Protection Agency, Washington, D.C.

Apr 78

U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-285 480

Development Document for Effluent Limitations Guidelines for the Pesticide Chemicals Manufacturing, Point Source Category

U.S. Environmental Protection Agency, Washington, D.C.

Apr 78

U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-285 480

DEVELOPMENT DOCUMENT FOR EFFLUENT LIMITATIONS GUIDELINES FOR THE PESTICIDE CHEMICALS MANUFACTURING, POINT SOURCE CATEGORY

GEORGE M. JETT

U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C.

APRIL 1978

EPA 440/1-78/060-e
Group II

PB 285 480

Development Document For Effluent Limitations Guidelines

for the

PESTICIDE CHEMICALS MANUFACTURING

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

Point Source Category

UNITED STATES ENVIRONMENTAL
PROTECTION AGENCY

APRIL 1978

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.
EPA 440/1-78/060-e

2\.

3. RECIPIENT'S ACCESSION NO.

4. TITLE AND SUBTITLE
Development Document for Final Effluent Limitations Guidelines for the Pesticide Chemicals Manufacturing Point Source Category

5. REPORT DATE
April 1978

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
George M. Jett

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Effluent Guidelines Division
WSM-E, Rm. 911, WH-552
401 M Street, S.W.
Washington, D. C. 20460

10. PROGRAM ELEMENT NO.
2BB156

11. CONTRACT/GRANT NO.

12. SPONSORING AGENCY NAME AND ADDRESS
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D. C. 20460

13. TYPE OF REPORT AND PERIOD COVERED
Final Development Document

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This document presents the findings of studies of the pesticide chemical manufacturing point source category for the purpose of developing effluent limitations guidelines for existing point sources to implement Sections 301(b) and 304(b) and of the Federal Water Pollution Control Act as amended (33 U.S.C. 1251 and 1314(b) and 86 Stat. 816 et. seq.) (the "Act"). Effluent limitations guidelines contained herein represent the application of the Best Practicable Control Technology Currently Available (BPT) as required by section 301(c) of the Act.

The pesticide chemicals manufacturing point source category is divided into three subcategories on the basis of the characteristics of the manufacturing processes involved and the types of products produced. The three subcategories are: the organic pesticide chemical subcategory, the metallo-organic pesticide chemical subcategory and the pesticide chemical formulation and packaging subcategory. Cost estimates have been developed for model treatment systems which are capable of attaining the effluent limitations. Supporting data and rationale for development of the effluent limitations are contained in this report and supporting file records.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Wastewater, Treatment, EPA, Regulations, BPT, Pesticides, Carbon, Hydrolysis, Biological Treatment, Herbicide, Fungicide		

18. DISTRIBUTION STATEMENT
Release Unlimited

19. SECURITY CLASS *(This Report)*

20. SECURITY CLASS *(This page)*

22. PRICE PC A14 MF A01

EPA Form 2220-1 (9-73)

DEVELOPMENT DOCUMENT
for
FINAL BPT
EFFLUENT LIMITATIONS GUIDELINES

for the

PESTICIDE CHEMICALS MANUFACTURING POINT SOURCE CATEGORY

George M. Jett
Project Officer

April 1978

Effluent Guidelines Division
Office of Water and Hazardous Materials
U.S. Environmental Protection Agency
Washington, D.C. 20460

ABSTRACT

This document presents the findings of studies of the pesticide chemicals manufacturing point source category for the purpose of developing effluent limitations guidelines for existing point sources to implement Sections 301(b) and 304(b) and of the Federal Water Pollution Control Act as amended (33 U.S.C. 1251 and 1314(b) and 86 Stat. 816 et. seq.) (the "Act").

Effluent limitations guidelines contained herein set forth the degree of effluent reduction attainable through the application of the Best Practicable Control Technology Currently Available (BPT) as required by section 301(b) of the Act.

The pesticide chemicals manufacturing point source category was originally divided into five subcategories on the basis of the characteristics of the manufacturing processes involved and the types of products produced. As a result of public comments and a reevaluation of the Agency's expanded data base, it was concluded that the subcategories for the halogenated organic, organo-phosphorus and organo-nitrogen pesticides as defined in the interim final regulations should be combined into the organic pesticide chemicals manufacturing subcategory (1). The subcategories for metallo-organics (2) and formulating and packaging (3) have remained the same.

Separate effluent limitations for the three subcategories have been derived based on the degree of treatment achievable by existing installations. Subcategory 1 plants employ combinations of biological and physical/chemical treatment methods. Facilities in subcategory 2 and 3 normally operate without the discharge of process waste water through recycle, evaporation or dry manufacturing. Cost estimates have been developed for model treatment systems which are capable of attaining the effluent limitations. Supporting data and rationale for development of the effluent limitations are contained in this report and supporting file records.

Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

TABLE OF CONTENTS

Section	Title	Page
	Abstract	vi
	Table of Contents	v
	List of Figures	vi
	List of Tables	ix
I	Conclusions	1
II	Recommendations	3
III	Introduction	5
IV	Industrial Categorization	57
V	Waste Characterization	63
VI	Selection of Pollutant Parameters	85
VII	Control and Treatment Technologies	103
VIII	Cost, Energy, and Non-Water Quality Aspects	155
IX	Best Practicable Control Technology Currently Available	179
X	Index of Common Pesticide Compounds by Subcategory	193
XI	Acknowledgements	267
XII	Bibliography	269
XIII	Glossary	311
XIV	Abbreviations and Symbols	315

Preceding page blank

LIST OF FIGURES

Number	Title	Page
III-1	Locations of Pesticide Production Plants	11
III-2	Locations of Formulation Facilities in U.S.	21
III-3	General Process Flow Diagram for DDT and Related Compounds Production Facilities	22
III-4	General Process Flow Diagram for Halogenated Phenol Production Facilities	25
III-5	General Process Flow Diagram for Aryloxyalkanoic Acid Production Facilities	26
III-6	General Process Flow Diagram for Aldrin-Toxaphene Production Facilities	28
III-7	General Process Flow Diagram for Halogenated Aliphatic Hydrocarbon Production Facilities	30
III-8	General Process Flow Diagram for Halogenated Aliphatic Acid Production Facilities	31
III-9	General Process Flow Diagram for Phosphates and Phosphonates Pesticide Production Facilities	33
III-10	General Process Flow Diagram for Phosphorothioate and Phosphorodithioate Production Facilities	35
III-11	General Process Flow Diagram for Alkyl and Aryl Carbamate Production Facilities	37
III-12	General Process Flow Diagram for Thiocarbamate Production Facilities	38
III-13	General Process Flow Diagram for Amide and Amine Production Facilities	40

III-14	General Process Flow Diagram for Urea and Uracils Production Facilities	42
III-15	General Process Flow Diagram for S-Triazine Production Facilities	44
III-16	General Process Flow Diagram for Nitro-type Pesticides	45
III-17	General Process Flow Diagram for Arsenic-type Metallo-Organic Production	47
III-18	General Process Flow Diagram for Certain Dithiocarbamate Metallo-Organic Production	49
III-19	Liquid Formulation Unit	51
III-20	Dry Formulation Unit	53
V-1	Flow Raw Waste Load Characteristics, Pesticides Manufacturers	77
V-2	BOD Raw Waste Load Characteristics, Pesticides Manufacturers	78
V-3	COD Raw Waste Load Characteristics, Pesticides Manufacturers	79
V-4	TSS Raw Waste Load Characteristics, Pesticides Manufacturers	80
V-5	Phenol Raw Waste Load Characteristics, Pesticides Manufacturers	81
V-6	Pesticide Raw Waste Load Characteristics, Pesticides Manufacturers	82
VII-1	Effect of pH and Temperature on Malathion Degradation	121
VII-2	Molecular Structures, Demeton-O and Demeton-S	122
VII-3	Bronstead Plot of the Second-Order Alkaline Hydrolysis Rate Constants of N-phenyl Carbamates versus pKa of the Resulting Alcohol at 25° C	124

VII-4	Bronstead Plot of the Second-Order Alkaline Hydrolysis Rate Constant of the N-alkyl Carbamates versus pKa of the Resulting Alcohol at 25° C	125
VII-5	Bronstead Free Energy Relationship, Dimethoxyphosphate Pesticides	133
VII-6	Bronstead Free Energy Relationships, Diethoxyphosphate Pesticides	134
VII-7	Bronstead Free Energy Relationship, Dimethoxyphosphorothioate Pesticides	136
VII-8	Bronstead Free Energy Relationship, Diethoxyphosphorothioate Pesticides	137
VII-9	Cost Treatment Technology--Subcategory 1	153

LIST OF TABLES

Number	Title	Page
II-1	BPT Effluent Limitations Guidelines	4
III-1	Pesticides Classification	12-13
III-2	Structural Chemistry of Typical and Major Pesticides	14-18
V-1	Summary of Potential Process-Associated Wastewater Sources from Organic Pesticide Production	64-65
V-2	Raw Waste Loads Organic Pesticide Manufactures-Subcategory 1	66-69
V-3	Summary of Potential Process-Associated Wastewater Sources from Metallo-Organic Pesticide Production	71
V-4	Raw Waste Loads, Metallo-Organic Pesticide Manufacturers-Subcategory 2	72-74
V-5	Summary of Potential Process-Associated Wastewater Sources from Pesticide Formulators and Packagers	75
V-6	Design Criteria, Cost Treatment Technology-Subcategory 1	83
VII-1	Direct Discharger Profile, Pesticide Chemicals Industry	105
VII-2	Indirect Discharger Profile, Pesticide Chemicals Industry	106-109
VII-3	Activated Carbon Design Summary, Pesticide Chemicals Industry	111
VII-4	Activated Carbon Summary Pesticide Industry	113
VII-5	Activated Carbon Isotherm and Dynamic Data, Pesticide Industry	118-119

VII-6	Full Scale Hydrolysis Data	126
VII-7	Hydrolysis Literature Data Organo-Phosphorus Pesticides	128-131
VII-8	Hydrolysis Literature Data Organo-Nitrogen Pesticides	132
VII-9	Biologically Treated Effluent Summary - Organic Pesticide Chemicals Manufacturers-Manufacturers-Subcategory 1	143-144
VII-10	Holding Pond Effluent, Plant 34	150
VIII-1	Basis for Computation of Capital Costs (July, 1977 Dollars)	157
VIII-2	Basis for Computation of Annual Costs (July, 1977 Dollars)	158
VIII-3	BPT Cost Itemization Excluding Pesticide Removal Units-Subcategory 1	167-168
VIII-4	BPT Cost Itemization, Hydrolysis 12,000 Minutes Detention-Subcategory 1	169
VIII-5	BPT Cost Itemization, Carbon-750 Minutes Detention-Subcategory 1	170
VIII-6	BPT Cost Summary, Pesticide Removal-Subcategory 1	171
VIII-7	BPT Cost Summary, All Treatment Units-Subcategory 1	172
VIII-8	Land Requirements Subcategory 1	173-174
VIII-9	BPT Cost Itemization-Subcategory 3	175
IX-1	BPT Effluent Limitation Guidelines	181
IX-2	Development of Long-Term Averages-Subcategory 1	183
IX-3	Variability Factors-Subcategory 1	185

IX-4	Upgrading of Existing Systems	189-190
X-1	Index of Pesticide Compounds By Subcategory	194-266
XIV-1	Metric Table	316

SECTION I

CONCLUSIONS

This document provides background information for BPT (Best Practicable Control Technology Currently Available) for the pesticide chemicals manufacturing point source category. The initial contractor's draft report was issued in February, 1975. The interim final report was revised and published in November, 1976. This report represents further revision of that interim final development document as a result of public comments and additional studies and data collection by the Agency.

This report marks a change from the earlier studies. The Agency had previously taken the approach that the major manufacturing process groups (halogenated organic, organo-phosphorus, and organo-nitrogen) were a basis for subcategorization. Additional information collected, combined with the existing data base, indicates that with the treatment scheme of pesticide removal, equalization, and biological treatment all waste waters generated from the manufacture of these pesticide chemicals can be satisfactorily treated to the same effluent limitations. The metallo-organic pesticide chemicals and pesticide chemicals formulating and packaging subcategories are unchanged from the interim final regulations.

For purposes of regulation, the three subcategories are:

1. Organic Pesticide Chemicals Manufacturing.

2. Metallo-Organic Pesticide Chemicals Manufacturing.

3. Pesticide Chemicals Formulating and Packaging.

Model treatment systems are presented for each subcategory in Section VII of this document. Costs for each model were developed and used to assess the economic impact to the pesticide industry. The treatment models should not be construed as the only technology capable of meeting the effluent limitations. There are many alternative systems which either singly or in combination are capable of attaining the effluent limitations in this Development Document.

It is expected that each individual plant will make the choice of the specific combination of pollution control measures best suited to its situation in complying with the regulations supported in this development document.

Process waste waters from Subcategory 1 may result from the following steps: decanting, distillation, stripping, extraction/precipitation, and purification. High organic and solids loadings may be caused by equipment cleanout, area washdowns, accidental spillage, or poor operation. Caustic scrubbers and contact cooling may contribute significantly to total flow.

For proper control and treatment, Subcategory 1 process waste waters should be isolated from nonprocess waste waters such as utility discharges and uncontaminated storm runoff. The BPT treatment technology for the process waste waters includes an API separator, pesticide removal by hydrolysis or multimedia filtration and activated carbon, equalization, neutralization, and activated sludge. In some cases incineration or suitable disposal of strong or toxic wastes may be necessary.

Process waste waters produced by facilities within Subcategory 2, the metallo-organic pesticide chemicals subcategory, are disposed of by recycle or suitable containment. BPT control and treatment of process waste waters for this subcategory is no discharge of process waste water pollutants.

Formulators and packagers within Subcategory 3 have been found to generate either no waste waters or such small volumes that disposal can be handled adequately by disposal contractors, land application, evaporation, or other means leading to no discharge of process waste water pollutants.

Pollutants or pollutant parameters of concern in this industry are BOD5, COD, TSS, and pesticide chemicals. Both phenol and ammonia nitrogen may be found at significant levels at a few plants. These latter two pollutants should be regulated on an individual basis.

It is not the intent of this document to cover the manufacture of intermediates used in the manufacture of the active ingredients. Like phenol and ammonia, the manufacture of pesticide chemical intermediates should be covered on a case-by-case basis.

Stormwater that does not commingle with the process waste water is likewise excluded from coverage by this document. The document is intended to cover process waste water discharged from a point source as defined in the Federal Water Pollution Control Act.

This regulation has also excluded coverage of certain pesticides, such as symmetrical and asymmetrical triazines, and tin, zinc, and manganese based metallo-organics. These compounds are under study, and the Agency intends to publish regulations to cover them in the future.

SECTION II

RECOMMENDATIONS

The effluent limitations for each subcategory are presented in Table II-1.

The effluent limitations consist of two limitations for each parameter: the maximum average of daily values for thirty consecutive days and the maximum for any one day. The limitations were calculated based on the long-term effluent averages of those plants with the model technologies installed and properly operating. These long-term averages, presented in Section IX, were multiplied by the daily and monthly variability factors presented in Section IX, in order to determine the final limitations.

Process waste waters subject to these regulations include all contact process water, but do not include noncontact sources such as boiler and cooling water blowdowns, sanitary wastes, and other similar nonprocess sources. This regulation does not include the waste waters from the manufacture of intermediates used in the manufacture of pesticide chemicals. Likewise, stormwater which does not commingle with the process waste water is not covered by this document.

Raw waste loads developed in Section V form the basis for cost estimates of the treatment technologies presented in Section VII. These cost estimates have been applied in Section IX to each direct discharger not in compliance in order to determine additional treatment costs due to this regulation. Precautions in applying these limitations are detailed in Section IX.

TABLE II-1

BPT EFFLUENT LIMITATIONS GUIDELINES

SUBCATEGORY[1]	EFFLUENT CHARACTERISTIC	EFFLUENT LIMITATIONS AVERAGE OF DAILY VALUES FOR 30 CONSECUTIVE DAYS	EFFLUENT LIMITATIONS DAILY MAXIMUM
1	BOD_5	1.6	7.4
	COD	9.	13.
	TSS	1.8	6.1
	Pesticide Chemicals	0.0018	0.010
	pH[2]	-	-
2	------NO DISCHARGE OF PROCESS WASTE WATER POLLUTANTS---------		
3	------NO DISCHARGE OF PROCESS WASTE WATER POLLUTANTS---------		

Note: All units are kg/kkg

1. Subcategory 1: Organic Pesticide Chemicals Manufacturing
   Subcategory 2: Metallo-Organic Pesticide Chemicals Manufacturing
   Subcateogry 3: Pesticide Chemicals Formulating and Packaging

2. The pH shall be between the values of 6.0 to 9.0

SECTION III

INTRODUCTION

Purpose and Authority

The Federal Water Pollution Control Act Amendments of 1972 (the Act) made a number of fundamental changes in the approach to achieving clean water. One of the most significant changes was a shift from a reliance on effluent limitations based on water quality to those based on technology.

The Act requires EPA to establish guidelines for technology-based effluent limitations which must be achieved by point sources of discharges into the navigable waters of the United States. Section 301(b)(1)(A) of the Act requires the achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best practicable control treatment currently available (BPT) as defined by the Administrator pursuant to Section 304(b) of the Act. Section 301(b)(2)(A) also requires the achievement by not later than July 1, 1983 of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the (BAT) best available technology economically achievable. This will result in progress toward reaching the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to Section 304(b) of the Act. Section 306 of the Act requires new source performance standards. These standards will reflect the greatest degree of effluent reduction which the Administrator determines to be achievable through the application of the new source performance standards (NSPS) processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants. Section 307(b)(1) of the Act requires the Administration to, from time to time, publish pretreatment standards for new and existing sources.

Section 304(b) of the Act requires the Administrator to publish regulations based on the degree of effluent reduction attainable through the application of the BPT and the best control measures and practices achievable, including treatment techniques, process and procedure innovations, operation methods, and other alternatives.

This document forms the technical basis for the BPT effluent limitations and guidelines promulgated pursuant to Sections 301(b)(1)(A) and 304(b) of the Act.

Methods Used for Development of the Effluent Limitations Guidelines

The effluent limitations guidelines presented in this document were developed in the following manner. The Agency completely reviewed the interim final regulations including the subcategorization schemes, and the data base presented in the interim final Development Document (EPA 440/1-75/060d) and its supplements. From this point the Agency began to collect additional data to determine if any changes needed to be made to the interim final regulations. Determination was then made as to whether further subcategorization would aid in description of the category. Such determinations were made on the basis of the combined data base including raw materials required, products manufactured, processes employed, and other factors.

The raw waste characteristics for each subcategory were identified. This included an analysis of: 1) the source and volume of water used in the process employed and the sources of wastes and waste waters in the plant, and 2) the constituents of all waste waters. The constituents of waste waters which should be subject to effluent limitations guidelines were identified.

The full range of control and treatment technologies existing within this industry was identified. This included an identification of each distinct control and treatment technology, including both in-plant and end-of-pipe technologies, which exist. It also included an identification of the effluent level resulting from the application of each of the treatment and control technologies in terms of the amount of constituents and of the chemical, physical, and biological characteristics of pollutants. The reliability of each treatment and control technology was also identified. In addition, the non-water quality environmental impacts (such as the effects of the application of such technologies upon other pollution problems, including air, solid waste, radiation, and noise) were also identified. The energy requirements of each of the control and treatment technologies were identified, as well as the cost of the application of such technologies.

This information was then evaluated in order to determine what level of technology constituted BPT. In identifying such technologies, factors considered included the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application, the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques, process changes, non-water quality environmental impacts (including energy requirements), and other factors.

During the first phases of the study, an assessment was made of the availability, adequacy, and usefulness of all existing data sources. Data on the identity and performance of waste water treatment systems included the following:

1. NPDES permit applications;
2. Self-reporting discharge data from various states and regions;
3. Surveys conducted by trade associations or by agencies under research and development grants.

A preliminary analysis of these data indicated an obvious need for further information in the following areas: 1) process raw waste load related to production; 2) currently practiced or potential in-plant waste control techniques; and 3) the identity and effectiveness of end-of-pipe treatment systems.

The best source of information was determined to be the manufacturers themselves. New information was obtained from telephone surveys, correspondence with the industry plant visits, and verification sampling. To date more than 133 pesticide chemicals manufacturing plants have been contacted and 32 visited. Visitations alone have covered more than 90 percent of the pesticide chemicals quantity manufactured.

The selection of waste water treatment plants to be visited was developed by identifying information available in the NPDES permit applications, state self-reporting discharge data, and by speaking with representatives of the manufacturing segment. Every effort was made to choose facilities where meaningful information on both treatment facilities and manufacturing processes could be obtained.

Collection of the data necessary for development of the effluent treatment capabilities within dependable confidence limits required analyses of both production and treatment operations. In a few cases, plant visits were planned so that the production operations of a single plant could be studied in association with an end-of-pipe treatment system which received only the wastes from that production. No significant differences were observed between plants manufacturing a single pesticide chemical and plants manufacturing multiple pesticides.

Survey teams composed of project engineers and scientists conducted the actual plant visits. Information on the identity and performance of waste water treatment systems was obtained through:

1. Interviews with plant water pollution control personnel or engineering personnel;
2. Examination of treatment plant design and historical operating data (flow rates and analyses of influent and effluent);
3. Treatment plant influent and effluent sampling.

Information on process plant operations was obtained through:

1. Interviews with plant operating personnel;
2. Examination of plant design and operating data (original design specification, flow sheets, and day-to-day material balances around individual process modules or unit operations where possible);
3. Individual process waste water sampling and analysis.

The data base obtained in this manner was then utilized to develop the effluent limitations for the pesticide chemicals manufacturing point source category. All of the references utilized are cited in Section XII of this report. Cost information is presented in Section VIII. Supporting data are available for examination at the EPA Public Information Reference Unit, Room 2922 (EPA Library), Waterside Mall, 401 M St. S.W., Washington, D.C. 20460.

Scope of the Document

The basic manufacture of organic pesticides is covered by this document. Representative pesticides covered by the final regulations are listed in Section X of this document. Other operations covered are: (1) establishments primarily engaged in the formulation and preparation of ready-to-use agricultural and household pest control chemicals, including insecticides, fungicides, and herbicides made from technical chemicals or concentrates; (2) the production of concentrates which require further processing before use and (3) establishments primarily engaged in manufacturing or formulating pesticide chemicals, not elsewhere classified, such as minor or trace elements and soil conditioners. The regulations that this document supports cover the formulation and packaging of all registered (FIFRA) pesticide chemicals regardless whether or not the manufacture of the active ingredient has been included.

The use of the term "pesticide" in this document refers to any chemical used to destroy a specific organism, i.e. an insecticide, herbicide, fungicide, miticide, etc.

This report does not cover the manufacture of non-pesticide products (such as plant hormones and soil conditioners) included in SIC codes 2819, 2869, and 2879. Also not covered in this document are those miscellaneous pesticide chemicals identified in Section X of this report. Coverage of the manufacture of pesticide intermediates used in the manufacture of pesticide active ingredients or stormwater that does not commingle with the process waste waters is likewise beyond the scope of this document.

Individual active ingredients are referred to by generic or chemical name, predominant trade name, competitive trade names, or abbreviation (e.g., DDT). This, and the fact that over 500 commercially important pesticides are manufactured, make individual references extremely difficult, and could be a source of confusion in this document. Therefore, throughout this document individual pesticide types will be referred to by their "common names". In a few instances, the generic or chemical name matches the common name. The common name is usually: (1) a hybrid of the original trade name, or (2) an abbreviation based on the chemical structure.

A better understanding of pesticides nomenclature can be obtained from the Pesticide Handbook-Entoma, Volume 1, pages 110-134, where a list of common names, chemical names, and alternative designations are presented.

It should be understood that specific pesticide manufacturing operations are unique and generally characteristic only of a given facility. There are very few, if any, pesticide plants which manufacture one product or use only one process. Instead, almost all plants are multiproduct/process facilities where the final mix of products shipped is unique to that plant. Some plants (such as batch chemicals complexes) produce hundreds of products, while other facilities manufacture only two or three high-volume products. In many instances, even the product mixes vary from day to day. Furthermore, the production quantities associated with the product mix shipped from a plant are not necessarily a true indication of the extent or type of manufacturing activities carried out within that plant. Frequently, products are utilized captively as feedstocks in the manufacture of other products. Few facilities manufacture or formulate pesticides exclusively; other chemicals may constitute a very minor or a very major portion of total production at a particular plant. These factors must be considered since water usage and waste water generation patterns in the pesticide chemicals point source category are directly related to the diverse nature of manufacturing processes and the availability of essential raw materials.

Overview of the Industry

The organic pesticide chemicals can be grouped by historical development. The distribution of major pesticide manufacturers is illustrated in Figure III-1. Unlike some point source categories where relatively large plants manufacture essentially a single product from a limited number of raw materials, the pesticide chemicals point source category involves a complex mixture of raw materials, processes, product mixes, and product formulations. There are 500 individual pesticides of commercial importance, and perhaps as many as 34,000 distinct major formulated products. During the course of the study every known manufacturer of organic pesticides was contacted.

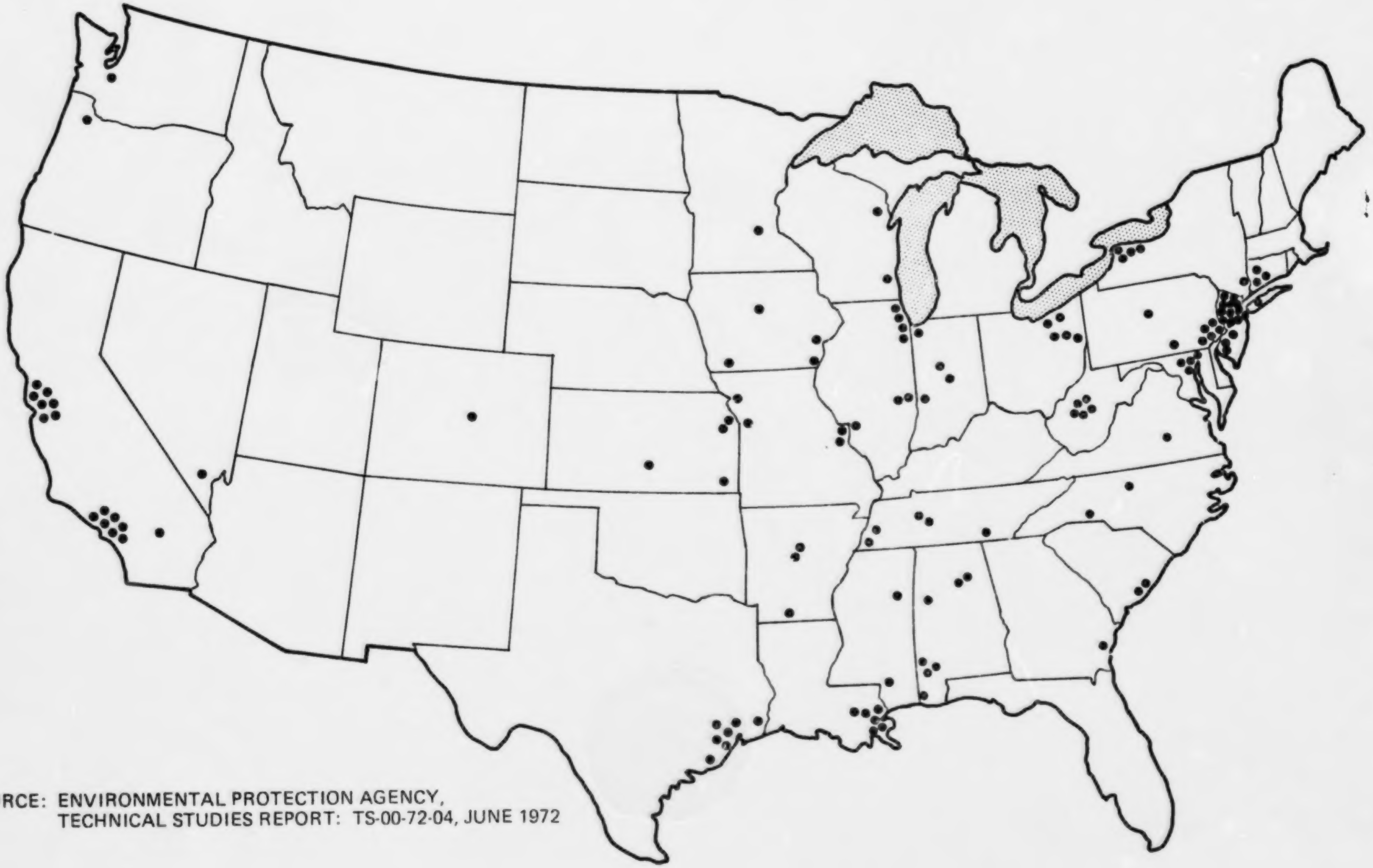
Table III-2 lists the majority of the pesticides manufactured in the U.S. according to family tree and chemical structure. Their chemical configuration is also illustrated in the table.

The halogenated pesticide chemicals group includes many first generation organic pesticides, e.g., DDT, and has a broad spectrum of insecticidal action with prolonged stability and residual activity. Competition from new products which are more economical, less toxic to higher animals, and more readily environmentally degradable, has caused a decline in the use of the halogenated organic group of pesticides since the mid-1960's.

The phosphorus-containing insecticides are among the fastest growing products in the pesticide chemicals industry. Thousands of phosphorus-containing compounds have been evaluated for pesticidal properties, and commercial products currently used include insecticides that are marketed in multimillion-pound quantities. The number of highly toxic, phosphorus-containing compounds is virtually limitless. Their suitability as insecticides, however, depends on their specific physical and chemical properties, and on how safely they can be employed. Although they are very toxic, phosphorus-containing compounds

FIGURE III -1

LOCATIONS OF PESTICIDES PRODUCTION PLANTS



SOURCE: ENVIRONMENTAL PROTECTION AGENCY,
TECHNICAL STUDIES REPORT: TS-00-72-04, JUNE 1972

TABLE III-1

PESTICIDE CLASSIFICATION

	NUMBER OF MAJOR PESTICIDES
Halogenated Organics	
DDT and relatives	9
Chlorinated Aryloxyalkanoic Acids	12
Aldrin-toxaphene group	16
Halogenated aliphatic hydrocarbons	20
Halogenated aromatic-type compounds, not elsewhere classified	29
Other chlorinated compounds	
	98
Phosphorus-Containing Pesticides	
Phosphates and phosphonates	19
Phosphorothioates and phosphorodithioates	61
Phosphorus-nitrogen compounds	8
Other phosphorus compounds	5
	93
Nitrogen-Containing Pesticides	
Aryl and alkyl carbamates and related compounds	35
Thiocarbamates	23
Anilides	13
Amides and amines (without sulfur)	24
Ureas and uracils	20
Triazines	14
Amines, heterocyclic (sulfur-containing)	12
Nitro compounds	26
Other nitrogen-containing compounds	42
	209
Metallo-Organic Pesticides	
Mercury compounds	28
Arsenic compounds	17
Other heavy metal compounds	17
Other inorganic compounds, including cyanides, phosphides, and related compounds	24
	86

TABLE III-1
PESTICIDE CLASSIFICATION
Continued

Page 2 of 2 pages

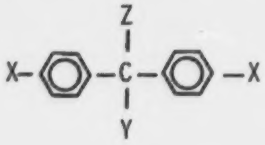
	NUMBER OF MAJOR PESTICIDES
Botanical and Microbiological Pesticides	19
Organic Pesticides, not Elsewhere Classified	
Carbon compounds	41
Anticoagulants	4
	45
TOTAL	550

TABLE III-2

STRUCTURAL CHEMISTRY OF TYPICAL AND MAJOR PESTICIDES

A. ORGANIC PESTICIDE CHEMICALS

DDT and Relatives



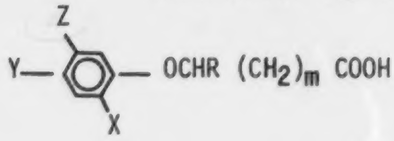
X=normally Cl

Y=noramlly CCl_3

Z=normally H

DDT, DDD, TDE, Perthane*,Methoxychlor, Prolan, Bulan, Gex, Dicofol, Chloropropylate, Bromopropylate, Parinol, Chlorobenzilate

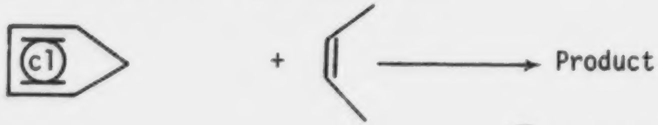
Chlorinated Aryloxyalkanoic Acids



R=normally H or CH_3
X=normally Cl
Y=always Cl
Z=normally H or Cl

2,4-D and its derivatives, 2,4,5-T and its derivatives, Silvex, Dichloroprop, Sesone, Fruitone CPA*, MCPA, MCPB, MCPP, Erbon

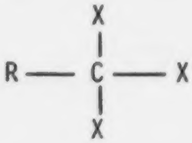
Aldrin - Toxaphene Group



(cl) = perchlorinated ring

Kepone*, Heptachlor, Mirex, Pentac*, Chlorodane, Telodrin, Aldrin, Dieldrin, Toxaphene, Endrin, Endosulfan, Isodrin, Alodan, Bromodan,

Halogenated Aliphatic Hydrocarbons



$$R-\overset{\displaystyle X}{\underset{\displaystyle X}{\overset{|}{\underset{|}{C}}}}-X$$

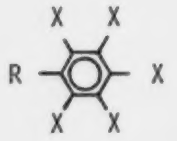
X=halogenated, H and O
R=Alkyl grouping or halogen

TCA and its salts, Dalapon and its salts, Fenac, Methyl Bromide, DBCP, DD*, EDB, Lindane, Glytac*

* Trademark

TABLE III-2
(Continued)

Halogenated Aromatic Compounds

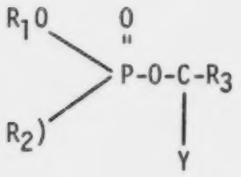


X=Cl, and NH_2,OCH_3, H, etc.

R=OH, H, CL, RCOOH, ESTER, etc.

Benzene hexachloride, Dichlorbenzenes, Dacthal*, PCP and its salts, Hexachlorophene, Chloroben, Hexachlorobenzene, Dicamba, Tricamba, Chloroneb, Probe, Fenac*, Piperalin, 2,3,6-TBA, TCBA, Tiba, Amiben, Propanil, Bandane, Strobane

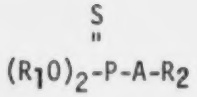
Phosphates and Phosphonates



R_1, R_2=usually alkyl group
R_3=Alkly, halogen, NH2, etc.
Y=ususally halogen on H

Dichlorvos, Dicrotphos, Ciodrin*, Trichlorofon, Ethephon, Gardona*, Mevinphos, Naled, Nia 10637, TEPP, Phosphamidon

Phosphorothioates and Phosphorodithioates


$$(R_1O)_2\text{-}\overset{\overset{S}{\parallel}}{P}\text{-}A\text{-}R_2$$

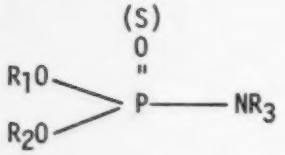
R_1=Alkyl group
A=O on S
R_2=Alkyl, aryl, NH_2, $CHBrCBrCl_2$, $CH\text{-}CCl_2$, etc.

Parathion, Me-Parathion, Dicapton, Chlorthion, Fenthion, Ronnel, Sumithion, Demeton, Diazinon, Dioxathion, Guthion*, Malathion, Coumaphos, Dasanit*, Phorate, Disulfoton, Ekatin, Abate*, Acetellic*, Pyrazophos, Akton*, Aspon*, Monocrotophos, Betasan*, DEF*, Dimethoate, Chlopyrifos, Dyfonate*, EPN, Ethion, Folex*, Phentriazophos, Imidan*, Menazon, Demeton-O-methylsulfoxide, Prophos, Phenthoate, Leptophos, Pirimiphosethyl, Sumithion*, Supracide*, Surecide*, Dialifor, Carbophenothion, Dichlorofenthion, Zinophos*, Phosalone

* Trademark

TABLE III-2
(Continued)

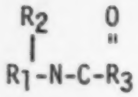
Phosphorus-Nitrogen Compounds



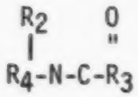
R_1=Alkyl, aryl group, etc.
R_2=Alkyl, aryl group, etc.
R_3=Alkyl, aryl, or other cyclic compounds, etc.

Ruelene, Nellite*, Nemacur*, Cyolane, Cytrolane, Go phacide*, Monitor*

Aryl and Alkyl Carbamates and Related Compounds



$R_1-\overset{R_2}{\overset{|}{N}}-\overset{O}{\overset{\|}{C}}-R_3$

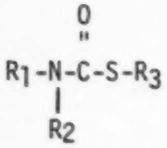


$R_4-\overset{R_2}{\overset{|}{N}}-\overset{O}{\overset{\|}{C}}-R_3$

R_1=Alkyl
R_2=Alkyl, H
R_3=Alkyl, NH_4, Etc.
R_4=Aryl group

Propham (IPC), Chloropropham (CIPC), Barban, Swep, Sirmate*, Azak*, Isolan, Metacrate*, Carbaryl (Sevin*), Zectran*, Metacil*, Baygon*, Mesurol*, Temik*, Banol, Meobal*, Landrin*, Betanol*, Asulox*, BUX, Carbofuran, Lannate*, Osbac*, Pirimicarb, Tandex*, Mobam*

Thiocarbamates

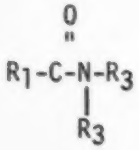


$R_1-\underset{R_2}{\underset{|}{N}}-\overset{O}{\overset{\|}{C}}-S-R_3$

R_1=Alkyl group
R_2=Alkyl, H
R_3= Alkyl, NH_4, etc.

EPTC, SMDC, Vernolate, CDEC, pebulate, Diallate, Triallate, butylate, Molinate, Cycloate, Bolero*, Eptam*

Amides and Amines (without sulfur)



$R_1-\overset{O}{\overset{\|}{C}}-\underset{R_3}{\underset{|}{N}}-R_3$

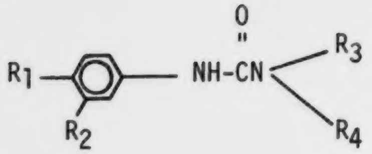
R_1=Alkyl, $ClCH_2$, etc.
R_2=Alkyl, Cyclic compounds
R_3=Alkyl, H

Pronamide, Alachlor, Dicryl, Solan, Propanil, Diphenamid, Propachlor, CDAA, Naptalam, Cypromid, CDA, Chlonitralid, Benomyl, Deet, Dimetilan, Diphenylamine, Horomodin*, Butachlor, Naphthalene acetamide, Vitavax*

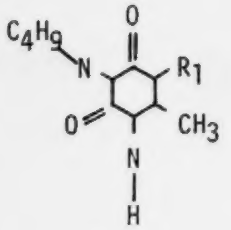
* Trademark

TABLE III-2
(Continued)

Ureas and Uracils



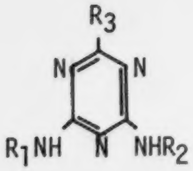
and



R_1=Cl, Br, H, OCH_3, etc.
R_2=H, Cl, etc.
R_3=CH_3, OCH_3, etc.
R_4=CH_3, Alkyl

Fenuron, Monuron, Diuron, Fluometuron, Linuron, Metobromuron, Momolinuron, Neburon, Siduron, Chloroxuron, Buturon, Chlorbromuron, Norea, Cycluron, Antu*, Metrobromuron, Monuron TCA, Probe*, Urab*, Bromacil

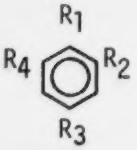
s-Triazines



R_1=Alkyl
R_2=Alkyl
R_3=Halogen, SCH_3, OCH_3, etc.

Ametryne, Atratone, Atrazine, Simazine, Simetone, Simetryne, Prometone, Prometryne, Propazine, Lambast*, Chlorazine, Bladex*, Prefox*, Sancap*, Sumitol*, Terbutryn, Dyrene*

Nitro Compounds



R_1=OH, Alkyl, Etc.
R_2=NO_2, H, Alkyl, etc.
R_3=NO_2, CF_3
R_4=NO_2, H

Benefin, Dinocap, Dinsep (DNSP), DNOC, Nitralin, PCNB, Trifluralin, A-820*, Dinoseb Acetate, Binapacryl, Dinitramine, Fluorodifen, Isoproplin, Lamprecid*, Torpedo*, Chloropicrin, DCNA

Other Nitrogen-Containinvg Compounds

These have varied chemical structures

Actellic*, Pyrazophos, Ametrole, Banamite*, Benomyl, Benzomate, Calixin*, Captan, Carzol*, Chlorodimeform, Cycloheximide, Cycoel*, Cyprex*, Dexon*, Diquat, Fenazaflor, Maleic hydrazide, MGK 264*,

* Trademark

TABLE III-2
(Continued)

MGK Repellent 326*, Neo-Pynamin*, Parquat, Thiram, Thiophanate, Thynon*, Milcurb*, Milstem*, Nia 21844, Nia 21861, Nia 23486, Nicotine, N-Serve*, Ohric*, Picloram, Piperalin, Plantvax*, Pyramin*, Ronstar*, Towtate*, SADH, Sencor*, Sicarol*, Stop Scald*, Streptomycin, Tandex*, Thanite*, Difolatan*, Folpet, Mertect*, Morestan*, Nia 19873, Niacide*,Ordram*, Terrazole*, Mylone (DMTT)

B. METALLO-ORGANIC

These have varied chemical structures, no generalized formula can be derived.

Brestan*, Cacodylic Acid, CMA, Manzate 200*, Copoloid*, Copper-8*, Copper Oleaste, DSMA, Du-Ter*, Ferbam, Maneb, MSMA, Nabam, Niacide*, Plictran*, Zineb, Ziram

C. BOTANICAL AND MICROBIOLOGICAL

These have varied chemical structures and, therefore, no generalized formula can be derived.

Bacillus popilliae, Bacillus thuringiensis, Polyhedrus Virus, Pyrethrins, Ryania

D. MISCELLANEOUS PESTICIDES (Not Elsewhere Classified)

These have varied chemical structures and, therefore, no generalized formula can be derived.

Cresotw, Nicotine, Rotenone, Petroleum oils, Butoxy, Calamite*, Dexon*, MGK Repellent 874*, Omite*, Sulfoxide, TCTP, Tetradifon

* Trademark

generally are easily hydrolyzed in an alkaline medium to yield materials of relatively low toxicity.

Several classes of nitrogen-containing compounds have been produced and successfully marketed since 1945. These have a broad range of biological activity, and can be applied as selective herbicides, insecticides, or fungicides. Herbicides and fungicides which contain nitrogen-compounds continue to increase their share of the pesticide market, an increase from 44.1 percent in 1966 to 57.2 percent in 1970.

Metallo-organic pesticide chemicals, which are produced by a relatively limited number of companies, include the sodium methane arsenate (MSMA) herbicides, and cadmium, mercury, and copper derivatives of organic compounds. Three major types of metallo-organic derivatives, manganese, tin and zinc, are not included in the scope of this document.

Several botanical and biological insecticides such as Bacillus thuriiqienes, the pyrethrins and rotenone are not covered in this study. Both production and waste water treatabilities of these compounds are similar to those of products discussed within the documents covering the pharmaceuticals, gum and wood chemicals, or organic chemicals point source categories. These products represent a small fraction of the pesticide chemicals industry. Rotenone is found widely in nature and is quite toxic to fish. These pesticides must be extracted or obtained through a fermentation process. Large-volume production (greater than one million pounds per year) is seldom encountered and limited treated waste data are available.

There are other pesticides which do not readily fall into the previously discussed groups. Of these, the rodenticide Warfarin deserves mention. Its production has exceeded 12 million pounds per year while none of the other so-called "miscellaneous" pesticides are produced in quantities greater than 1 million pounds per year. Warfarin did not fit into the interim final pesticide chemical groupings and was excluded from the regulations. It is the intent of the Agency to review this compound in the near future and publish regulations that will regulate the discharge from manufacture of Warfarin.

The treatability of the waste waters generated during the production of sulfur-based compounds is similar to that of their non-sulfur relatives. Inorganic pesticides such as sodium chlorate and elemental sulfur have been studied as part of the inorganic chemicals industry and are not covered in this document. Likewise, certain organic materials occasionally used as pesticides are more appropriately covered by the organic chemicals point source category.

In addition to the plants which manufacture active ingredients there are plants which make pesticide products by formulating, blending, canning, and packaging operations. Locations of formulation facilities are shown in Figure III-2. In formulating and packaging the raw materials used are the pesticide active ingredients, which may be procured from outside suppliers or may be manufactured on-site. The processing types in this subcategory (called formulators and packagers) are mechanical and physical/ chemical in nature. The levels of waste water generation and contamination are either considerably lower than in the active-ingredient production and are sometimes nonexistent. Pesticide formulations and packaged products generally fall into three classifications: water-based, solvent-based, and dry-based. Coverage for this subcategory includes all formulations registered under FIFRA.

Subcategory 1--Organic Pesticide Chemicals

The organic pesticide chemicals can be divided for discussion into three major groupings: halogen, phosphorus, and nitrogen based compounds.

Four major halogenated compounds merit discussion. These groups are:

DDT and its relatives
Chlorinated phenols and aryloxyalkanoic acids
Aldrin and toxaphene
Halogenated aliphatic compounds

Chlorinated compounds are the most common of the halogenated compounds and, in most cases, are illustrative of the processes and wastes associated with the other halogenated organic pesticides.

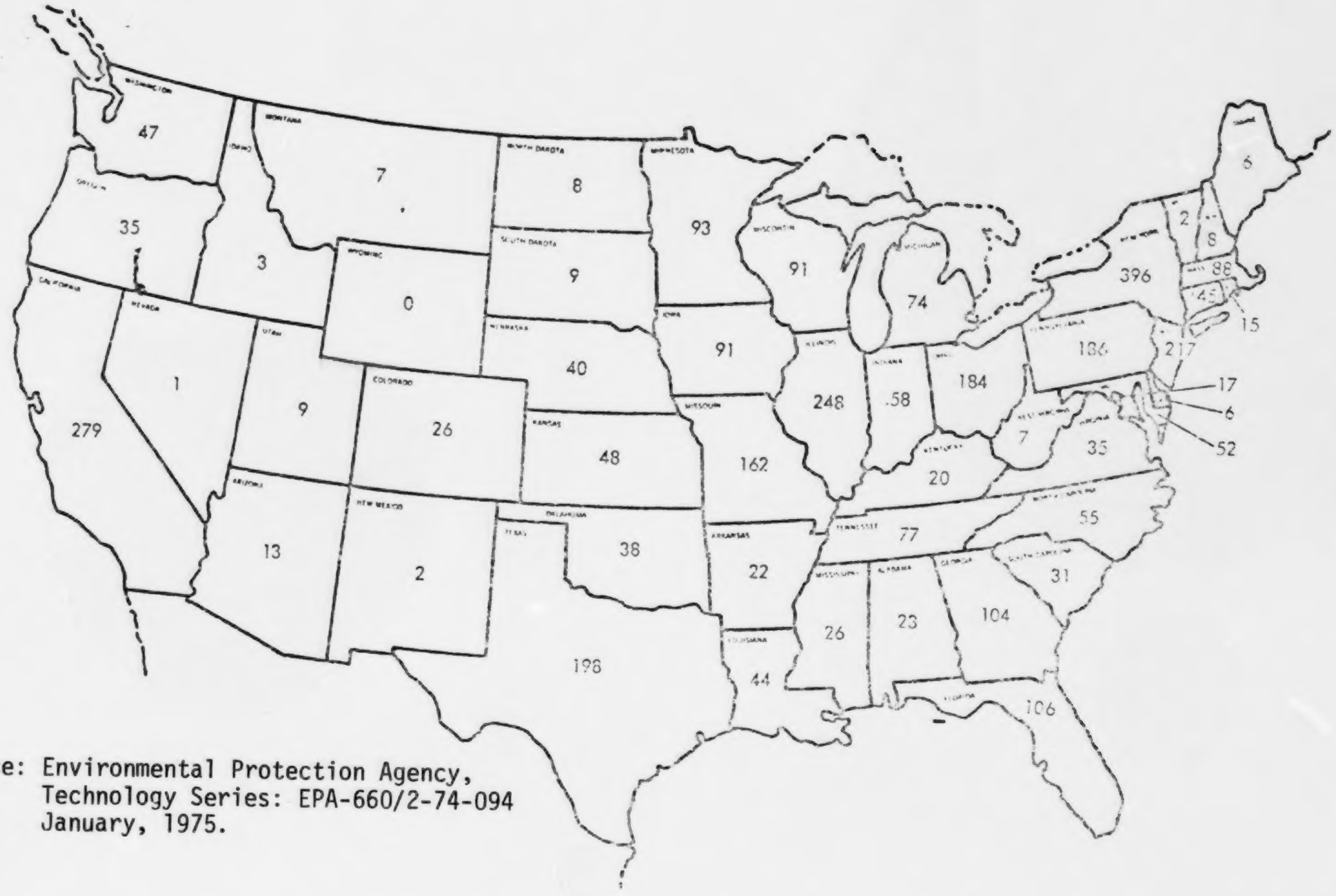
DDT and its relatives

Although present DDT production is on the decline, its manufacture is well documented in the literature and serves as a good example of the production and associated waste waters for the DDT family of pesticides. Analogs of DDT can be prepared by changing the substituents on the benzene base (e.g. Methoxychlor is made from Arisole and Chloral).

Figure III-3 is a simplified process flow diagram for DDT production and illustrates the type of waste water generated.

FIGURE III-2

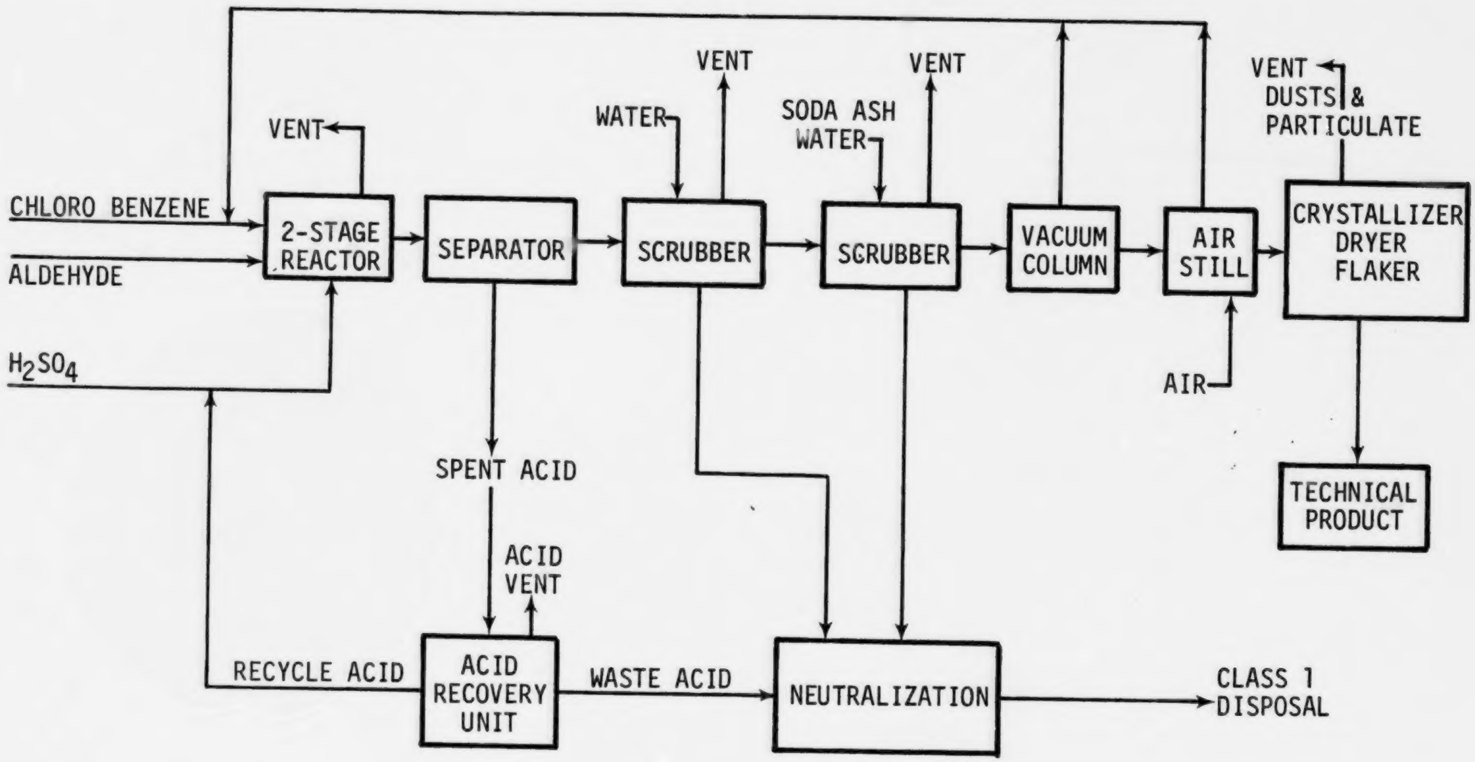
LOCATIONS OF FORMULATION FACILITIES IN U.S.


WASHINGTON
47
MONTANA
7
NORTH DAKOTA
8
MINNESOTA
93
IDAHO
OREGON
35
3
SOUTH DAKOTA
9
WISCONSIN
91
MICHIGAN
74
NEW YORK
396
2
8
MASS.
88
45
15
WYOMING
0
CALIFORNIA
NEVADA
NEBRASKA
40
IOWA
91
ILLINOIS
248
INDIANA
58
OHIO
184
PENNSYLVANIA
186
217
17
6
52
1
UTAH
9
COLORADO
26
KANSAS
48
MISSOURI
162
WEST VIRGINIA
7
VIRGINIA
35
279
KENTUCKY
20
ARIZONA
13
NEW MEXICO
2
OKLAHOMA
38
TEXAS
198
ARKANSAS
22
TENNESSEE
77
NORTH CAROLINA
55
SOUTH CAROLINA
31
MISSISSIPPI
26
ALABAMA
23
GEORGIA
104
LOUISIANA
44
FLORIDA
106

Source: Environmental Protection Agency,
Technology Series: EPA-660/2-74-094
January, 1975.

FIGURE III-3

GENERAL PROCESS FLOW DIAGRAM FOR DDT AND
RELATED COMPOUNDS PRODUCTION FACILITIES


CHLORO BENZENE
ALDEHYDE
H_2SO_4
VENT
2-STAGE REACTOR
SEPARATOR
WATER
VENT
SCRUBBER
SODA ASH WATER
VENT
SCRUBBER
VACUUM COLUMN
AIR STILL
AIR
VENT DUSTS & PARTICULATE
CRYSTALLIZER DRYER FLAKER
TECHNICAL PRODUCT
SPENT ACID
ACID VENT
RECYCLE ACID
ACID RECOVERY UNIT
WASTE ACID
NEUTRALIZATION
CLASS 1 DISPOSAL

VENT: GASES ARE SCRUBBED (COLLECTED AND NEUTRALIZED)
DUSTS TO BAGHOUSE (COLLECTED AND RETURNED TO FORMULATION)

The process description that follows is an example of how the process(es) may be carried out commercially, although considerable variations exist in process equipment design, reactant concentrations, amount of recycle acid, and methods of purification.

An aldehyde, chlorobenzene, and concentrated (95-99 percent) sulfuric acid or oleum are charged to a steel reactor. Generally the aldehyde and chlorobenzene are mixed together with part of the concentrated sulfuric acid. External cooling or cooling by means of internal coils is generally necessary to maintain the desired reaction temperature. The batch reaction can take several hours, or may be run continuously by using a number of reactors in series.

At the end of the reaction, the crude product goes to separators where the spent acid separates. This acid contains small amounts of water and is concentrated for re-use. The product liquor from the top of the separator goes to a liquid-phase scrubber, where water is used to remove mechanically entrained sulfuric acid. The liquor is then washed with dilute caustic or sodium carbonate solution in a second scrubber and finally washed with water. The separator and scrubber are maintained at sufficiently high temperature to prevent product crystallization.

The neutralized product containing chlorobenzene can be run to a column where it is vacuum-distilled. The chlorobenzene distillate is passed through a separator and condenser and is finally pumped to storage for recycling. The molten product containing a small percent of chlorobenzene can be pumped to a still, where additional chlorobenzene is removed by continuous atmospheric distillation. The melt is maintained at a temperature high enough to prevent crystallization of the product.

The chlorobenzene-free product melt is generally run to a flaker (consisting of a chilled drum rotating through a steam heated feed trough) where it is chilled to flakes. The flaked product is then pulverized to the proper mesh size and either packaged in concentrated form or blended with inert extenders.

It is becoming standard practice to recycle as much spent acid as possible and to raise the acid concentration to the desired level by the addition of oleum.

In the purification and finishing of the product, the most common solvents used are petroleum fractions and excess chlorobenzene. In order to pulverize the product adequately, entrained solvent must be reduced to as low a concentration as possible. Some manufacturers develop friability by aging the product; others by grinding in the presence of dry ice.

In summary, the process wastes associated with the production of DDT and its analogs are:

1. Waste acid from acid recovery unit
2. Scrub water from liquid phase scrubber
3. Dilute caustic waste water from caustic soda scrubber
4. Production area clean-up wastes
5. Scrubber water from vent gas water scrubbers
6. Water of formation from chemical reaction.

Chlorinated Phenols and Aryloxyalkanoic Acids

Chlorobenzenes are used as a starting material in the manufacture of chlorinated phenols and in the manufacture of chlorinated aryloxyalkanoic acid pesticides. Figures III-4 and III-5 are simplified process flow diagrams for the manufacture of the chlorinated phenols and aryloxyalkanoic acids. Potential waste water sources are shown.

Chlorobenzene can be converted to a phenol by reacting with dilute caustic soda or water and a catalyst in a reactor. Pentachlorophenol (PCP) is prepared by chlorinating the phenol in the presence of a catalyst (see Figure III-4). Excess hydrogen chloride and chlorine can be scrubbed with phenol and recycled to the reactor. The free hydrogen chloride is recycled to the chlorine plant. The crude PCP is distilled with NaOH to form the sodium salt.

Halogenated aryloxyalkanoic acids can be prepared by charging equimolar quantities of a chlorophenol and a monochloroalkyl acid to a steam-heated closed kettle in the presence of dilute caustic. The method of synthesis for 2, 4-dichlorophenoxyacetic acid (2,4-D) is generally applicable to the majority of the class. The reaction is carried on for several hours under reflux conditions, after which time the reaction mass is acidified (to approximately pH = 1.0) with dilute hydrochloric acid. The acidified liquor is sent to a crystallizer followed by a centrifuge. The reaction is carried out under optimum conditions of time, temperature, and rate of addition of reactants to prevent hydrolysis of unconverted chloroalkyl acid. In one process variation, unreacted dichlorophenol is removed by distillation prior to acidification. In still another variation, the reaction is carried out in anhydrous monochlorobenzene (as a solvent) at the boiling point of the solvent; water is removed

FIGURE III-4

GENERAL PROCESS FLOW DIAGRAM FOR
HALOGENATED PHENOL PRODUCTION FACILITIES

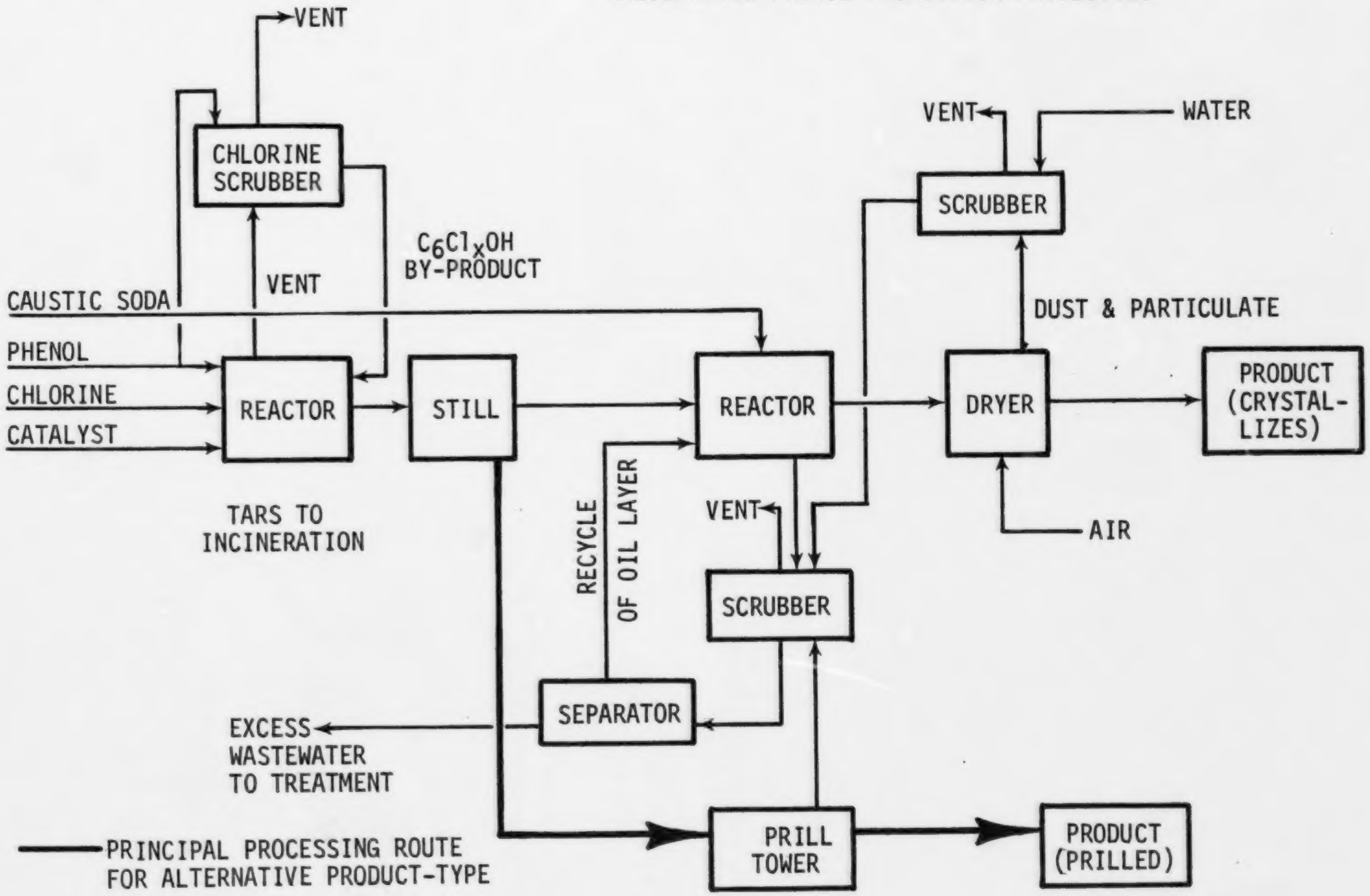
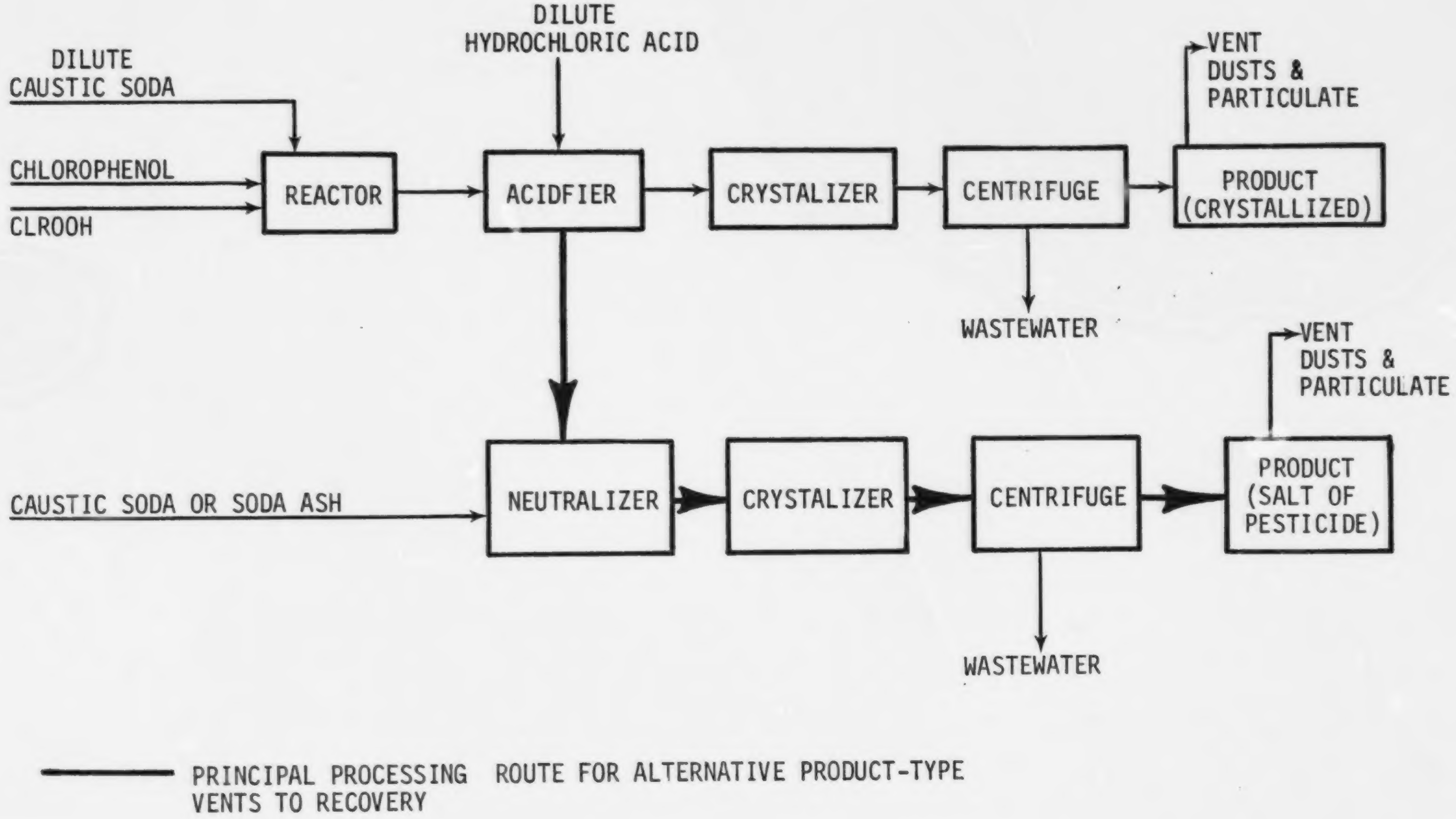

VENT
CHLORINE SCRUBBER
VENT
C_6Cl_xOH BY-PRODUCT
CAUSTIC SODA
PHENOL
CHLORINE
CATALYST
REACTOR
STILL
TARS TO INCINERATION
REACTOR
RECYCLE OF OIL LAYER
VENT
SCRUBBER
SEPARATOR
EXCESS WASTEWATER TO TREATMENT
PRILL TOWER
PRODUCT (PRILLED)
VENT
WATER
SCRUBBER
DUST & PARTICULATE
DRYER
PRODUCT (CRYSTAL-LIZES)
AIR
PRINCIPAL PROCESSING ROUTE FOR ALTERNATIVE PRODUCT-TYPE

FIGURE III-5

GENERAL PROCESS FLOW DIAGRAM OF ARYLOXYALKANOIC ACID PRODUCTION FACILITIES


DILUTE CAUSTIC SODA
CHLOROPHENOL
CLROOH
REACTOR
DILUTE HYDROCHLORIC ACID
ACIDFIER
CRYSTALIZER
CENTRIFUGE
WASTEWATER
VENT DUSTS & PARTICULATE
PRODUCT (CRYSTALLIZED)
CAUSTIC SODA OR SODA ASH
NEUTRALIZER
CRYSTALIZER
CENTRIFUGE
WASTEWATER
VENT DUSTS & PARTICULATE
PRODUCT (SALT OF PESTICIDE)
PRINCIPAL PROCESSING ROUTE FOR ALTERNATIVE PRODUCT-TYPE
VENTS TO RECOVERY

azeotropically. The insoluble product is separated from solvent by filtration.

Esters and amine salts are prepared by reacting the phenoxy alkyl acid with an alcohol or amine, respectively. These products have better formulation and application properties.

Briefly, waste waters generated from the production of this group of pesticides are:

1. Excess prill tower dust scrubber water
2. Centrate from liquid/solid separation step
3. Vent gas scrubber waters
4. Reactor and processing unit cleanout waste waters
5. Processing area washdown waste waters
6. Water of formation from chemical reaction.

Aldrin-Toxaphene Group

The insecticides of this group, except for Toxaphene and Strobane which are discussed below, are polychlorinated cyclic hydrocarbons with endomethylene-bridged structures, prepared by the Diels-Alder diene reaction. The development of these materials resulted from the 1945 discovery of chlordane, the chlorinated product of hexachlorocyclopentadiene and cyclopentadiene. Figure III-6, a simplified process flow diagram for this type of pesticide, illustrates the potential sources of waste water in this process.

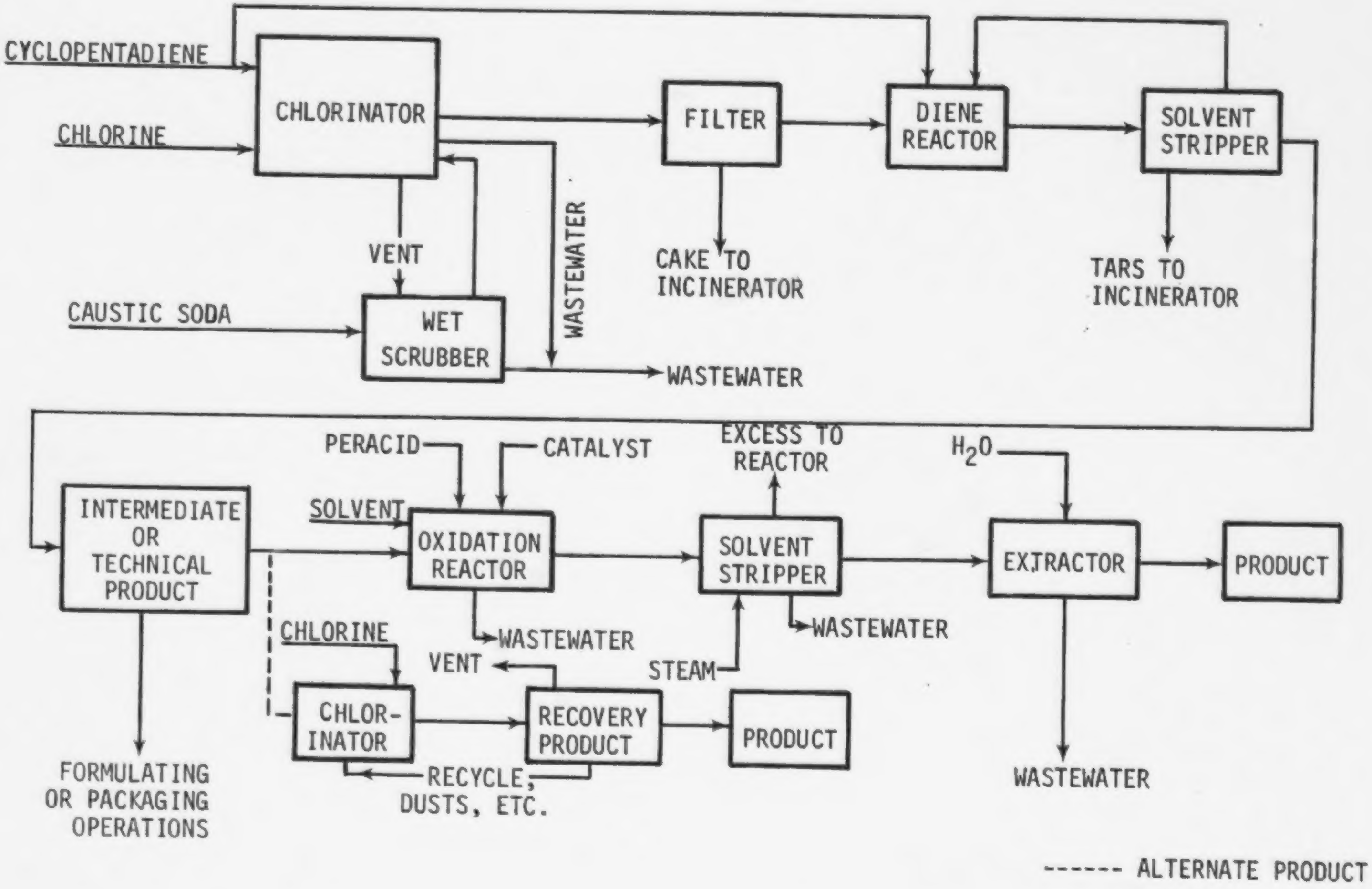
Cyclopentadiene, produced by cracking naphtha, is chlorinated to yield hexachlorocyclopentadiene (CPD), the raw material basic to the chemistry of this group of pesticides. Cyclopentadiene and various vinyl organic compounds can be combined with CPD in the Diels-Alder reactor.

Certain pesticides in this group can be epoxidized with hydrogen peroxide or peracids to produce an analogous group of pesticide compounds.

Toxaphene and Strobane are members of a group of incompletely characterized, broad-spectrum, insecticidal compounds produced by the chlorination of naturally occurring terpenes. They are insoluble in water and generally have long residual effects. These compounds, are unstable in the presence of alkali. Upon prolonged exposure to sunlight, and at temperatures above 155°C hydrogen chloride is liberated.

FIGURE III-6

GENERAL PROCESS FLOW DIAGRAM FOR ALDRIN-TOXAPHENE PRODUCTION FACILITIES


CYCLOPENTADIENE
CHLORINE
CHLORINATOR
VENT
CAUSTIC SODA
WET SCRUBBER
WASTEWATER
WASTEWATER
FILTER
CAKE TO INCINERATOR
DIENE REACTOR
SOLVENT STRIPPER
TARS TO INCINERATOR
INTERMEDIATE OR TECHNICAL PRODUCT
FORMULATING OR PACKAGING OPERATIONS
PERACID
CATALYST
SOLVENT
OXIDATION REACTOR
WASTEWATER
CHLORINE
CHLOR-INATOR
VENT
RECOVERY PRODUCT
RECYCLE, DUSTS, ETC.
PRODUCT
EXCESS TO REACTOR
SOLVENT STRIPPER
WASTEWATER
STEAM
H_2O
EXTRACTOR
PRODUCT
WASTEWATER
------ ALTERNATE PRODUCT

Wastewater generated in the production of this family of pesticides are:

1. Vent gas scrubber water from caustic soda scrubber
2. Aqueous phase from the epoxidation step
3. Wastewater from the water wash and product purification units
4. Periodic equipment cleaning waste water
5. Wastes from cleanup of production areas.

Tars, off-specification products and filter cake should not generate waste waters since they are usually incinerated.

Halogenated Aliphatic Hydrocarbons

This group includes chlorinated aliphatic acids and their salts (e.g., TCA, Dalapon, and Fenac herbicides), halogenated hydrocarbon fumigants (e.g., methyl bromide, DBCP, and EDB), and the insecticide Lindane. Figures III-7 and III-8 represent simplified process flow diagrams for the production of halogenated aliphatics and halogenated aliphatic acid pesticides. Potential waste water sources are illustrated.

Chlorinated aliphatic acids can be prepared by nitric acid oxidation of chloral (TCA), or by direct chlorination of the acid. The acids can be sold as mono- or di-chloro acids, or neutralized to an aqueous solution with caustic soda. The neutralized solution is generally fed to a dryer from which the powdered product is packaged.

Wastewaters potentially produced during the manufacture of pesticides in this groups are:

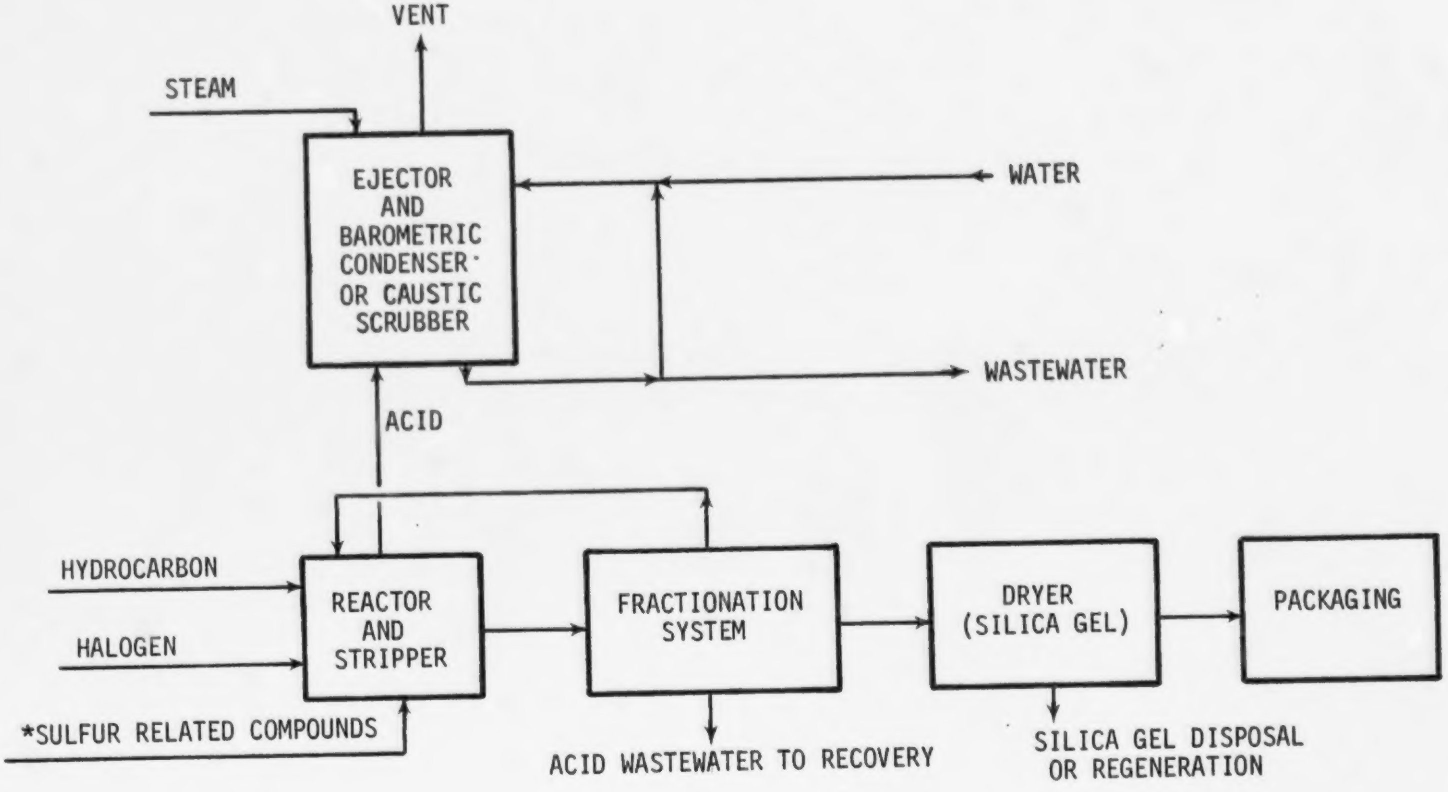
1. Condensate from steam jets
2. Acidic waste water from fractionation units
3. Cooler blowdown water
4. Excess mother liquor from centrifuges
5. Vent gas scrubber water from caustic soda scrubber
6. Aqueous phase from decanter units
7. Scrubber water from dryer units
8. Wash water from equipment cleanout
9. Process area clean up wastes.

Phosphorus-Containing Pesticides

The commercial organo-phosphorus pesticides, composed of phosphates, phosphonates, phosphorothioates, phosphorodithioates,

FIGURE III-7

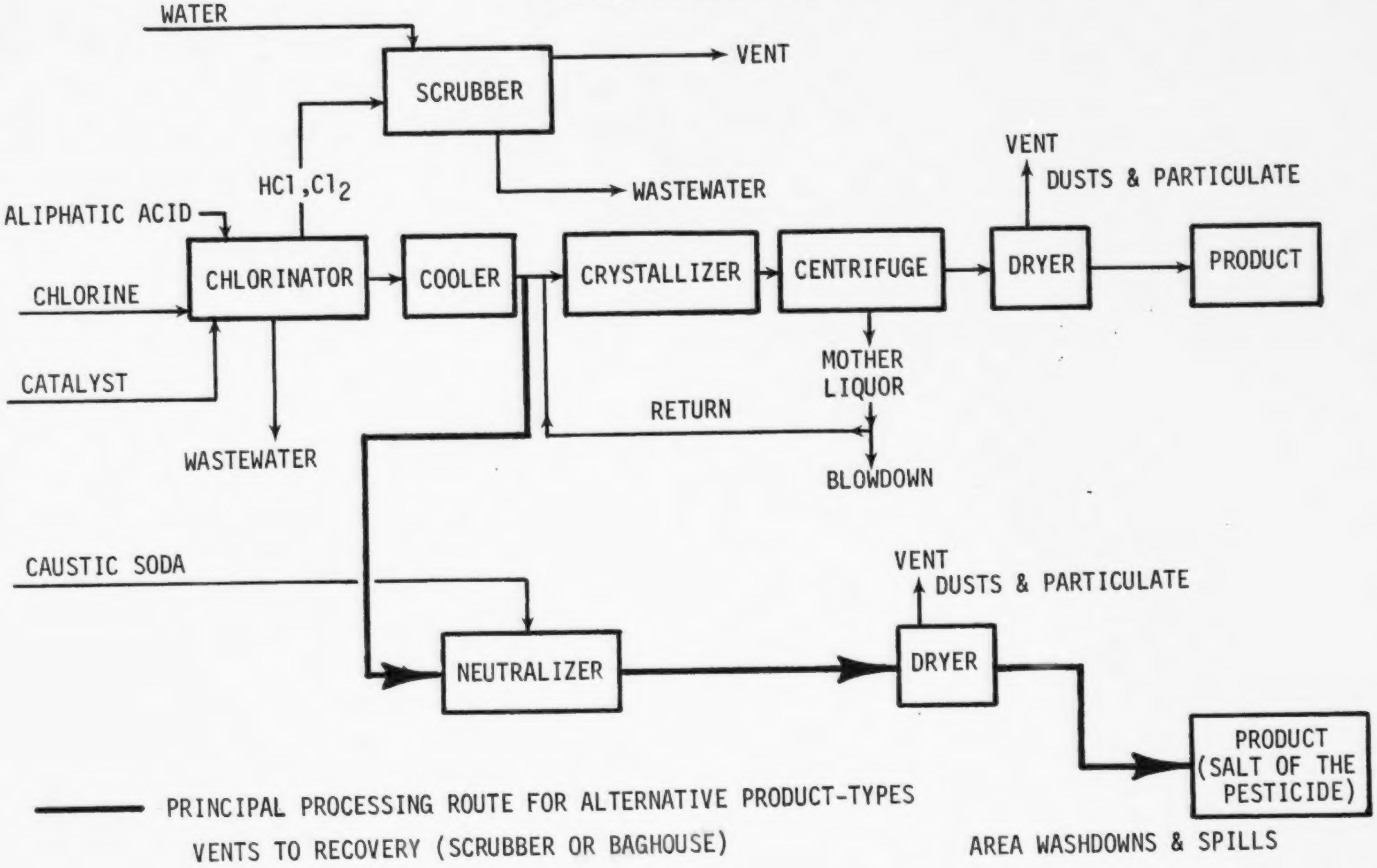
GENERAL PROCESS FLOW DIAGRAM FOR HALOGENATED ALIPHATIC HYDROCARBON PRODUCTION FACILITIES


VENT
STEAM
EJECTOR AND BAROMETRIC CONDENSER OR CAUSTIC SCRUBBER
WATER
WASTEWATER
ACID
HYDROCARBON
HALOGEN
*SULFUR RELATED COMPOUNDS
REACTOR AND STRIPPER
FRACTIONATION SYSTEM
DRYER (SILICA GEL)
PACKAGING
ACID WASTEWATER TO RECOVERY
SILICA GEL DISPOSAL OR REGENERATION

* SULFUR RELATED COMPOUNDS IS A RAW MATERIAL FOR PRODUCTS

FIGURE III-8

GENERAL PROCESS FLOW DIAGRAM FOR HALOGENATED ALIPHATIC ACID PRODUCTION FACILITIES


WATER
SCRUBBER
VENT
WASTEWATER
HCl,Cl2
ALIPHATIC ACID
CHLORINE
CATALYST
CHLORINATOR
WASTEWATER
COOLER
CRYSTALLIZER
CENTRIFUGE
MOTHER LIQUOR
RETURN
BLOWDOWN
VENT
DUSTS & PARTICULATE
DRYER
PRODUCT
CAUSTIC SODA
NEUTRALIZER
VENT
DUSTS & PARTICULATE
DRYER
PRODUCT (SALT OF THE PESTICIDE)
PRINCIPAL PROCESSING ROUTE FOR ALTERNATIVE PRODUCT-TYPES
VENTS TO RECOVERY (SCRUBBER OR BAGHOUSE)
AREA WASHDOWNS & SPILLS

and phosphorus-nitrogen compounds, account for about 95 percent of the phosphorus-containing pesticides produced today.

Seven of the 10 most popular organo-phosphorus compounds start with the preparation of a phosphite triester (P (ORD) 3) which can be readily oxidized to the respective phosphates, but is more commonly reacted with a ketone or aldehyde having an alpha-carbon halide. The product thus formed is a phosphate with an unsaturated aliphatic grouping. These compounds can then be halogenated across the double bond to form yet another compound with pesticidal properties.

Phosphates and Phosphonates

Phosphates and phosphonates, such as trichlorfon, dischlovos, TEPP and ethephon are grouped as phoshpite triesters. Figure III-9 is a simplified process flow diagram of phosphite triester production showing potential waste water sources.

In the manufacture of the phosphite triester, an alcohol and phosphorus trichloride are fed to a reactor using a base (for example, sodium carbonate) to produce the crude product, with hydrogen chloride as a by-product. The phosphite triester is then reacted with a chloroketone or chloraldehyde in a reactor/stripper vessel. Light-ends are continuously removed under vacuum. The condensible fraction containing the by-product, alkyl halide, can be recovered but is generally wasted. Noncondensibles captured in the steam condensate go to treatment.

The technical-grade intermediate dissolved in an inert solvent is then halogenated. After halogenation in a batch reactor/stripper, the vented gas is scrubbed with a solution of caustic soda. This waste water goes to treatment. Then under reduced pressure, the solvent is removed, condensed and recycled back to the reactor. Condensate from the steam jet system is collected for treatment.

Generally, ketone or aldehyde are manufactured on-site, and the resulting waste water usually become part of the "pesticide" process wastes.

Phosphorothioates and Phosphorodithioates

This family of pesticides includes the parathions, malathion, ronnel, diazinon, Guthion, Dasanit, disulfoton, dimethoate, chlopyrifos, ethion, Folex, and carbophenothion, each of which is produced in greater than one million pounds quantity annually.

FIGURE III-9

GENERAL PROCESS FLOW DIAGRAM FOR PHOSPHATES AND PHOSPHONATES PESTICIDE PRODUCTION FACILITIES

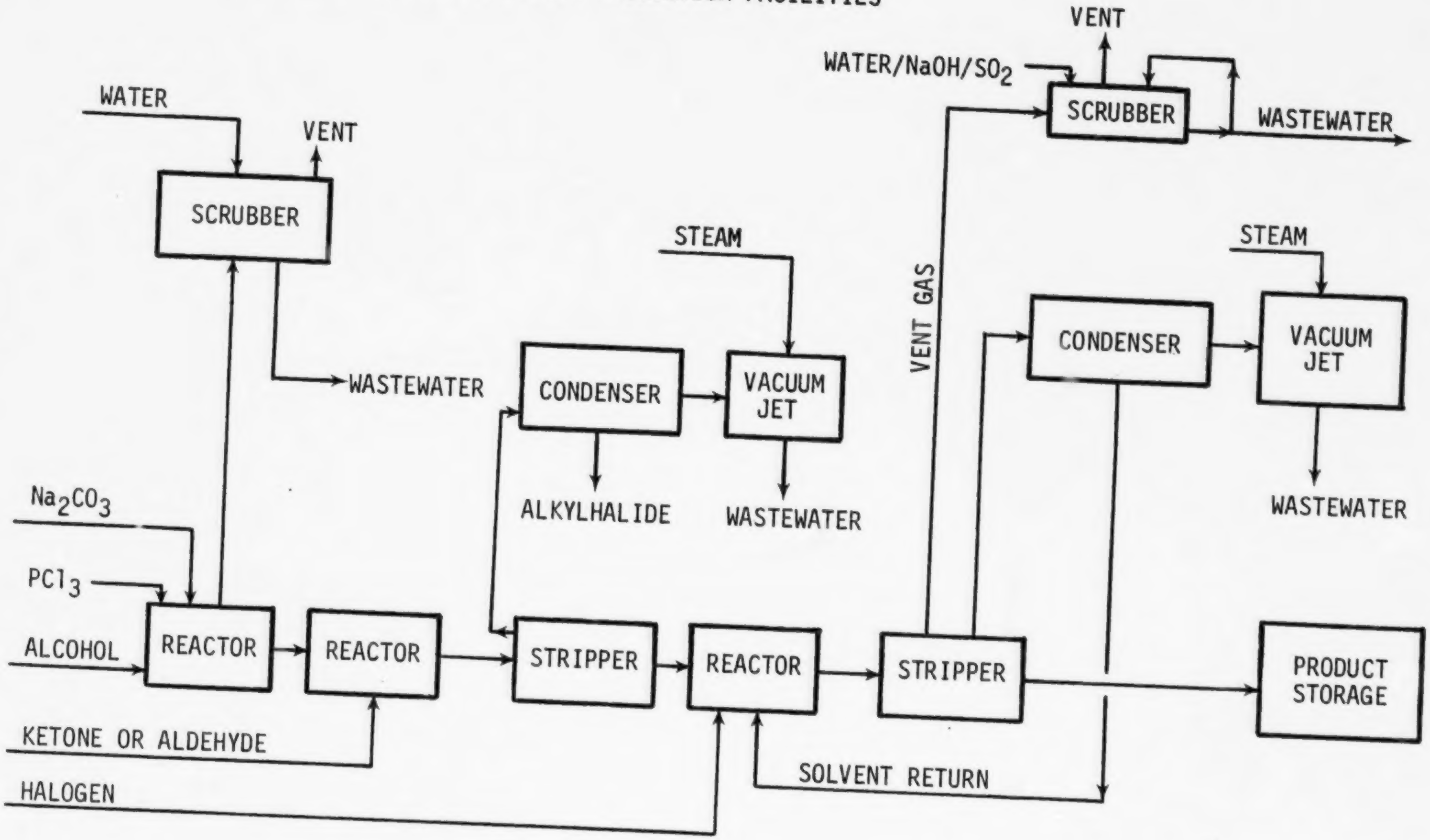

VENT
WATER/NaOH/SO$_2$
SCRUBBER
WASTEWATER
WATER
VENT
SCRUBBER
STEAM
STEAM
VENT GAS
CONDENSER
VACUUM JET
WASTEWATER
CONDENSER
VACUUM JET
Na_2CO_3
ALKYLHALIDE
WASTEWATER
WASTEWATER
PCl_3
ALCOHOL
REACTOR
REACTOR
STRIPPER
REACTOR
STRIPPER
PRODUCT STORAGE
KETONE OR ALDEHYDE
SOLVENT RETURN
HALOGEN

Figure III-10 is a generalized process and waste flow diagram for this group of compounds. In the first step, phosphorus pentasulfide (P_2S_5) is reacted with an alcohol (generally in a solvent) to form the dialkyl phosphorodithioic acid (dithio acid). This is an anhydrous reaction.

The dithio acid can then be: (1) converted to a dithio salt, (2) chlorinated to the dialkyl phosphorochloridothionate (DAPCT), or (3) reacted, with an aldehyde or an alkene to form a desired intermediate or product.

Using the production of the dithio salt as an example, caustic soda is added to the dithio acid in a separate reactor to produce the dithio salt. The dithio salt in the aqueous phase is separated to be used in the next reaction step. The organic phase serves to remove residuals, namely unreacted triester. Solvent is recovered and returned to the dithio acid unit. Wastes from the solvent recovery step are sent to treatment.

The dithio acid can also be chlorinated to produce a phosphorochloriridithionate (PCT) which can combine with the dithio salt in a condensation step. The crude PCT can be purified by distillation. Distillation residues are hydrolyzed, yielding sulfur and phosphoric acid as by-products. Organic wastes require treatment, usually incineration.

The dithio acid can be further reacted with an aldehyde or alkene under slightly acidic conditions in a batch process. Caustic soda is added to maintain the correct pH. In the recovery system, product is recovered, water-washed, and then air dried. The recovery step waste products include distillation wastes and solids (filter cake). Acid waste water from the wash step is combined with scrubber water from the overhead drier. Together, these waste waters constitute the major portion of the process waste stream.

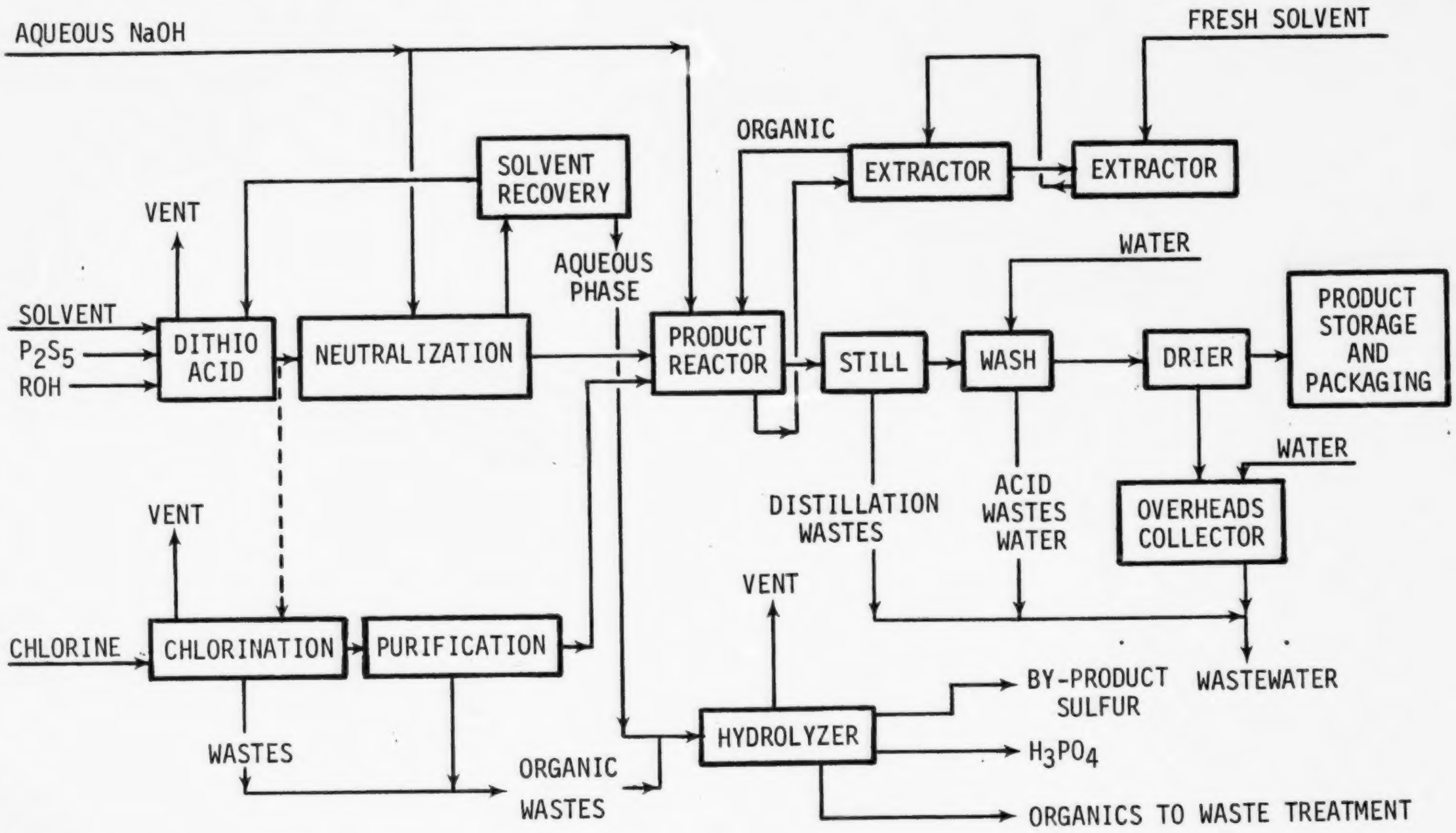
Pesticide removal from process waste water should take place (via alkaline hydrolysis at elevated temperatures, carbon sorption, etc.) before combining with other plant waste streams.

In summary, the following waste waters are generated during the production of organo-phosphorus compounds:

1. Hydrolyzer waste water
2. Aqueous phase from product reactors
3. Wash water from product purification steps
4. Aqueous phase from solvent extractor
5. Wastewater from overhead collectors and caustic soda vent gas scrubbers

FIGURE III-10

GENERAL PROCESS FLOW DIAGRAM FOR PHOSPHOROTHIOATE AND PHOSPHORODITHIOATE PRODUCTION FACILITIES


AQUEOUS NaOH
FRESH SOLVENT
ORGANIC
EXTRACTOR
EXTRACTOR
SOLVENT RECOVERY
VENT
AQUEOUS PHASE
WATER
SOLVENT
P_2S_5
ROH
DITHIO ACID
NEUTRALIZATION
PRODUCT REACTOR
STILL
WASH
DRIER
PRODUCT STORAGE AND PACKAGING
WATER
DISTILLATION WASTES
ACID WASTES WATER
OVERHEADS COLLECTOR
VENT
VENT
CHLORINE
CHLORINATION
PURIFICATION
BY-PRODUCT SULFUR
WASTEWATER
HYDROLYZER
WASTES
ORGANIC WASTES
H_3PO_4
ORGANICS TO WASTE TREATMENT

VENT GASES
H_2S. THERMAL OXIDIER
HCl. PARTIAL RECOVERY

6. Reactor and process equipment cleanout waste waters
7. Area washdowns

Organo-Nitrogen Processes

The nitrogenous pesticides include the greatest number of chemical types, the broadest raw material base, and the most diverse process schemes. Product and process types to be described are the aryl- and alkylcarbamates, thiocarbamates, amides and amines, ureas and uracils, triazines, and the nitroaromatics.

Aryl and Alkyl Carbamates and Related Compounds

The carbamates in this grouping include carbaryl, carbofuran, chloropropham, BUX, aldicarb and propoxur. A generalized production flow diagram is shown in Figure III-11 together with the principal wastewater sources.

In general, carbamates are synthesized in a combination of batch and continuous processes. Wastes include liquid streams, vents and some heavy residues. Pesticide wastes will require detoxification (via alkaline hydrolysis) before being sent to the general plant treatment system. Vents are flared or pass through a caustic scrubber. Heavy residue requires incineration.

Wastewaters associated with the production of these compounds are:

1. Brine process waste water from reactors
2. Wastewater from the caustic soda scrubbers
3. Aqueous phase wasted following the isocyanate reaction
4. Reactor cleanout washwater
5. Area washdowns

Thiocarbamates

This family of pesticides include Eptam, butylate, vernolate, pebulate and ETPC. In a series of semi-continuous and batch operations, as shown in Figure III-12, phosgene is reacted with an amine to give a carbamoyl chloride. Reaction of the carbamoyl chloride with a mercaptan gives the corresponding thiocarbamate.

Alternatively, the amine can be reacted with an alkyl chlorothiolformate to yield the thiocarbamate. Thiocarbamates are generally volatile compounds, and therefore, can be distilled.

FIGURE III-11

GENERAL PROCESS FLOW DIAGRAM FOR ALKYL AND ARYL CARBAMATE PRODUCTION FACILITIES

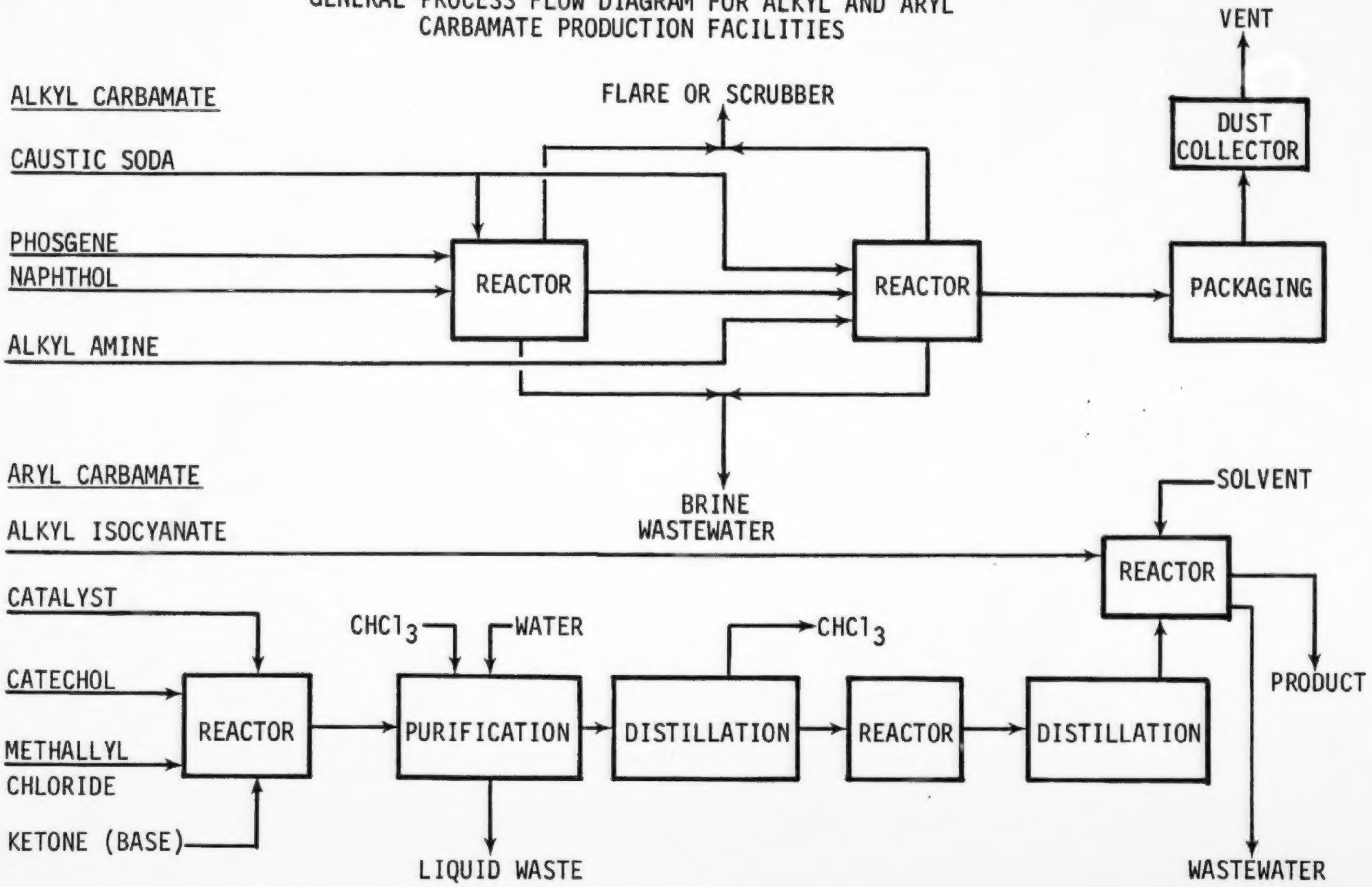
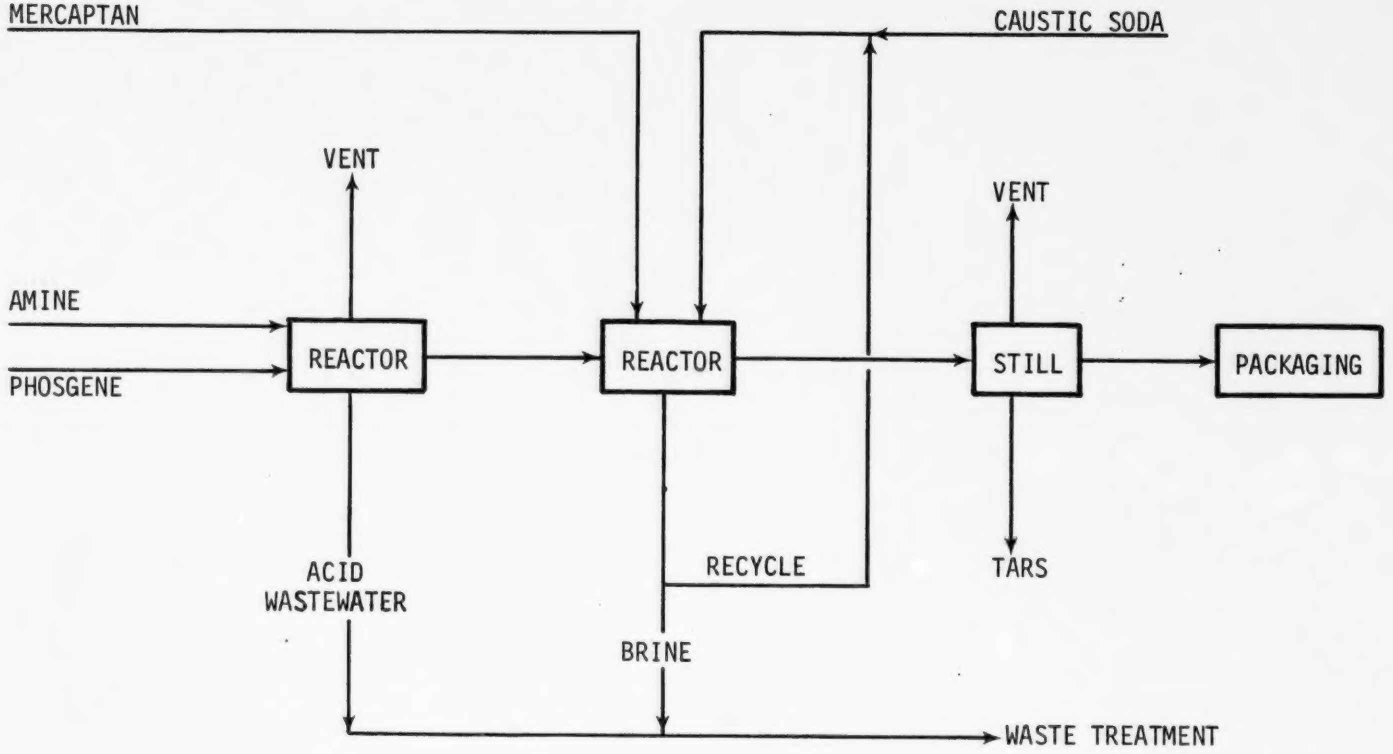

VENT
ALKYL CARBAMATE
FLARE OR SCRUBBER
DUST COLLECTOR
CAUSTIC SODA
PHOSGENE
NAPHTHOL
REACTOR
REACTOR
PACKAGING
ALKYL AMINE
ARYL CARBAMATE
SOLVENT
BRINE WASTEWATER
ALKYL ISOCYANATE
REACTOR
CATALYST
$CHCl_3$
WATER
$CHCl_3$
CATECHOL
PRODUCT
METHALLYL CHLORIDE
REACTOR
PURIFICATION
DISTILLATION
REACTOR
DISTILLATION
KETONE (BASE)
LIQUID WASTE
WASTEWATER

FIGURE III-12

GENERAL PROCESS FLOW DIAGRAM FOR
THIOCARBAMATE PRODUCT FACILITIES


MERCAPTAN
CAUSTIC SODA
VENT
VENT
AMINE
PHOSGENE
REACTOR
REACTOR
STILL
PACKAGING
ACID
WASTEWATER
RECYCLE
TARS
BRINE
WASTE TREATMENT

Acidic process waste waters from the first reactor are combined with the brine wastes from the second reactor, and together mixed with vent gas scrubber water before treatment. Still bottoms are generally incinerated. Liquid wastes are biodegradable, especially following acid or alkaline hydrolysis at elevated temperatures.

In summary, the production of thiocarbamates will generate the following waste waters:

1. Acid waste water from the initial reaction step
2. Brine from the second reaction step
3. Wastewater from caustic soda scrubbers
4. Kettle clean-out wash waters
5. Area washdowns.

Amides and Amines (without sulfur)

Compounds in this group include Deet, naptalam, CDAA, propachlor, alachlor, propanil and diphenamid, each of which has been produced at greater than one million pounds per year. Typically, these herbicides include two major groups: herbicides based on substituted anilide structures and chloroacetamide derivatives.

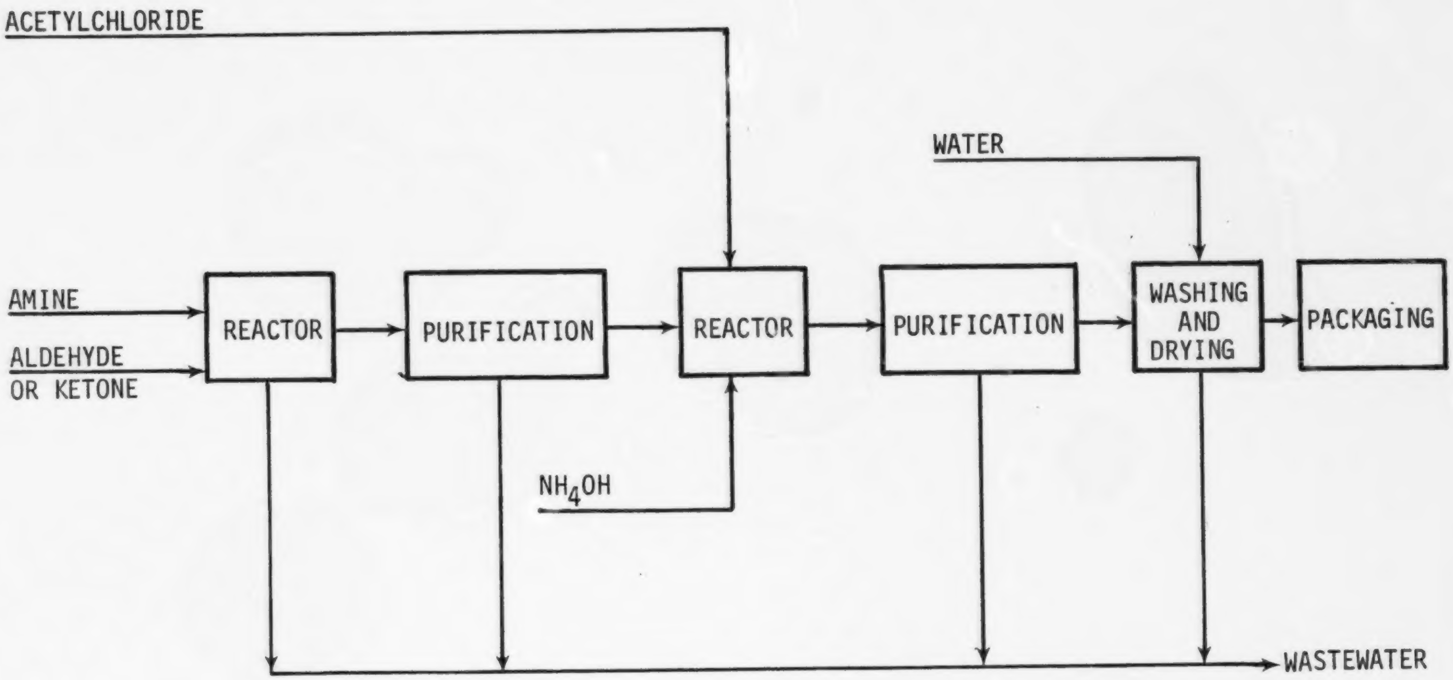
A generalized process flow diagram, indicating waste water sources, is presented in Figure III-13. Briefly, the process is based on the reaction of an acetyl chloride with a suitable amine. Generally, the amine is prepared within the same plant. Wastewater from the preparation of the amine can be included in the raw waste load for the production of these pesticides. Such waste waters are generated from the intermediate product separation and purification steps. If the acetyl chloride is also prepared on-site, then acidic process waste water from the purification step and vent gas scrubbers should be considered part of the overall pesticide raw waste water loads.

In summary, waste waters resulting from the production of the amide and amine group of pesticides are:

1. Aqueous fractions from reactors
2. Wastewater from purification steps
3. Vacuum jet condensate
4. Wastewater removed in purification step
5. Water from washing steps
6. Kettle cleanout wastes
7. Area washdowns

FIGURE III-13

GENERAL PROCESS FLOW DIAGRAM FOR
AMIDE AND AMINE PRODUCTION FACILITIES


ACETYLCHLORIDE
WATER
AMINE
ALDEHYDE
OR KETONE
REACTOR
PURIFICATION
REACTOR
PURIFICATION
WASHING
AND
DRYING
PACKAGING
NH4OH
WASTEWATER

Ureas and Uracils

Pesticides in this group include diuron, monuron fluometuron, linuron and norea urea compounds and the herbicide bromacil, each of which has a production level in excess of one million pounds per year.

The production of monuron is typical of the general process used to manufacture this family of pesticides. Figure III-14 shows the generalized process flow diagram and waste water sources associated with the production process. Reaction of para-chloroaniline in dioxane or another inert solvent with anhydrous hydrogen chloride and phosgene generates para-chlorophenyl isocyanate, which then can be reacted with dimethylamine to yield monuron. Another commercial process involves the reaction of an aniline and urea, in alcohol or phenol solvent, to generate the phenyl isocyanate, which is further reacted with an appropriate amine. The ureas are generally insoluble in the inert solvent and precipitate out. The inert solvent can be flash-distilled and recycled to the reactor. Aqueous hydrochloric acid is added to the crude product to remove insoluble components. The product is then water washed in a precipitator to yield the final product.

Uracils are a relatively new class of herbicides whose group is growing. The process illustrated in Figure III-14 is as follows: an alkylamine, phosgene, and ammonia are reacted to yield an alkyl urea; following a caustic wash purification step, the alkyl urea is then reacted with an alkyl acetoacetate, caustic washed and neutralized with sulfuric acid; the uracil can then be halogenated (commonly with bromine), filtered, dried and finally packaged.

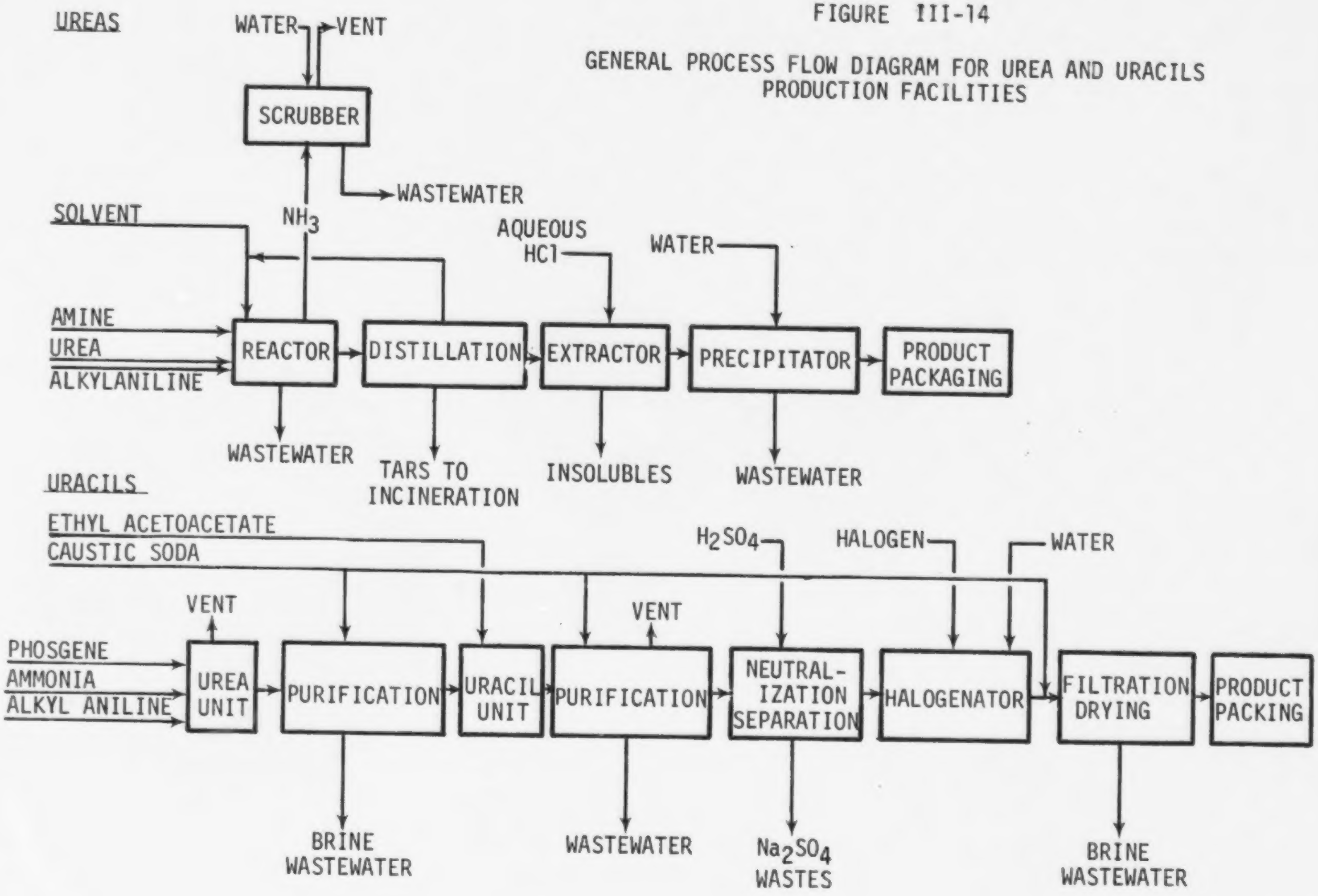
No solid wastes are generated and no significant quantities of chemicals are recycled. Liquid wastes from the purification, neutralization and filtration steps require treatment via either biological oxidation or incineration technologies.

In summary, waste waters generated in the manufacture of urea and uracil pesticides can be as follows:

1. Aqueous wastes from precipitator (Urea)
2. Scrubber waters (Urea and Uracil)
3. Brine from purification steps (Uracil)
4. Aqueous sodium sulphate from neutralization and intermediate product separations (Uracil)
5. Brine from filtration
6. Reactor wash water (Urea and Uracil)
7. Production area washdowns (Urea and Uracil)

FIGURE III-14

GENERAL PROCESS FLOW DIAGRAM FOR UREA AND URACILS PRODUCTION FACILITIES


UREAS
WATER
VENT
SCRUBBER
WASTEWATER
SOLVENT
NH3
AQUEOUS HCl
WATER
AMINE
UREA
ALKYLANILINE
REACTOR
DISTILLATION
EXTRACTOR
PRECIPITATOR
PRODUCT PACKAGING
WASTEWATER
TARS TO INCINERATION
INSOLUBLES
WASTEWATER
URACILS
ETHYL ACETOACETATE
CAUSTIC SODA
H2SO4
HALOGEN
WATER
VENT
VENT
PHOSGENE
AMMONIA
ALKYL ANILINE
UREA UNIT
PURIFICATION
URACIL UNIT
PURIFICATION
NEUTRAL-IZATION SEPARATION
HALOGENATOR
FILTRATION DRYING
PRODUCT PACKING
BRINE WASTEWATER
WASTEWATER
Na2SO4 WASTES
BRINE WASTEWATER

s-Triazines

The starting material for the production of the s-triazines is cyanuric chloride. It is obtained industrially by trimerization of cyanogen chloride. A generalized process flow diagram showing potential wastewater sources is presented in Figure III-15. One chlorine atom is replaced by an amine, phenol, alcohol, mercaptan, thiophenol or a related compound under controlled reaction conditions. Hydrogen chloride and hydrogen cyanide gases are evolved and vented. The gases pass through a caustic soda scrubber, and the resulting scrubber waste water requires treatment.

Amination of the cyanuric chloride, as depicted in Figure III-15, requires one to three steps in a continuous process. Solvent can be recovered and recycled to the process. The liquid wastes are combined with the caustic scrubber waters prior to combined treatment.

Dust generated in formulation and packaging is collected in a baghouse and then returned to process. Vapors are caustic scrubbed and combined with other process waste streams.

In summary, waste waters generated in the production of triazine herbicides generally come from the following sources:

1. Caustic soda scrubbing and filtration of vented HCl and HCN gases
2. Aqueous wastes from the solvent recovery unit
3. Scrubber water from the air pollution control equipment used in formulation areas
4. Production area washdowns
5. Reactor clean-out wash waters

Nitro Compounds

This family of organo-nitrogen pesticides includes the nitro phenols (and their salts), for example, dinoseb, and the substituted dinitroanilines, trifluralin and nitralin, each of which amounts to more than one million pounds annually of active ingredients.

An example of a typical commercial process for the production of a dinitroaniline herbicide is illustrated in Figure III-16. In this example, a chloroaromatic is charged to a nitrator with cyclic acid and fuming nitric acid. The crude product is then

FIGURE III-15

GENERAL PROCESS FLOW DIAGRAM FOR S-TRIAZINE PRODUCTION FACILITIES

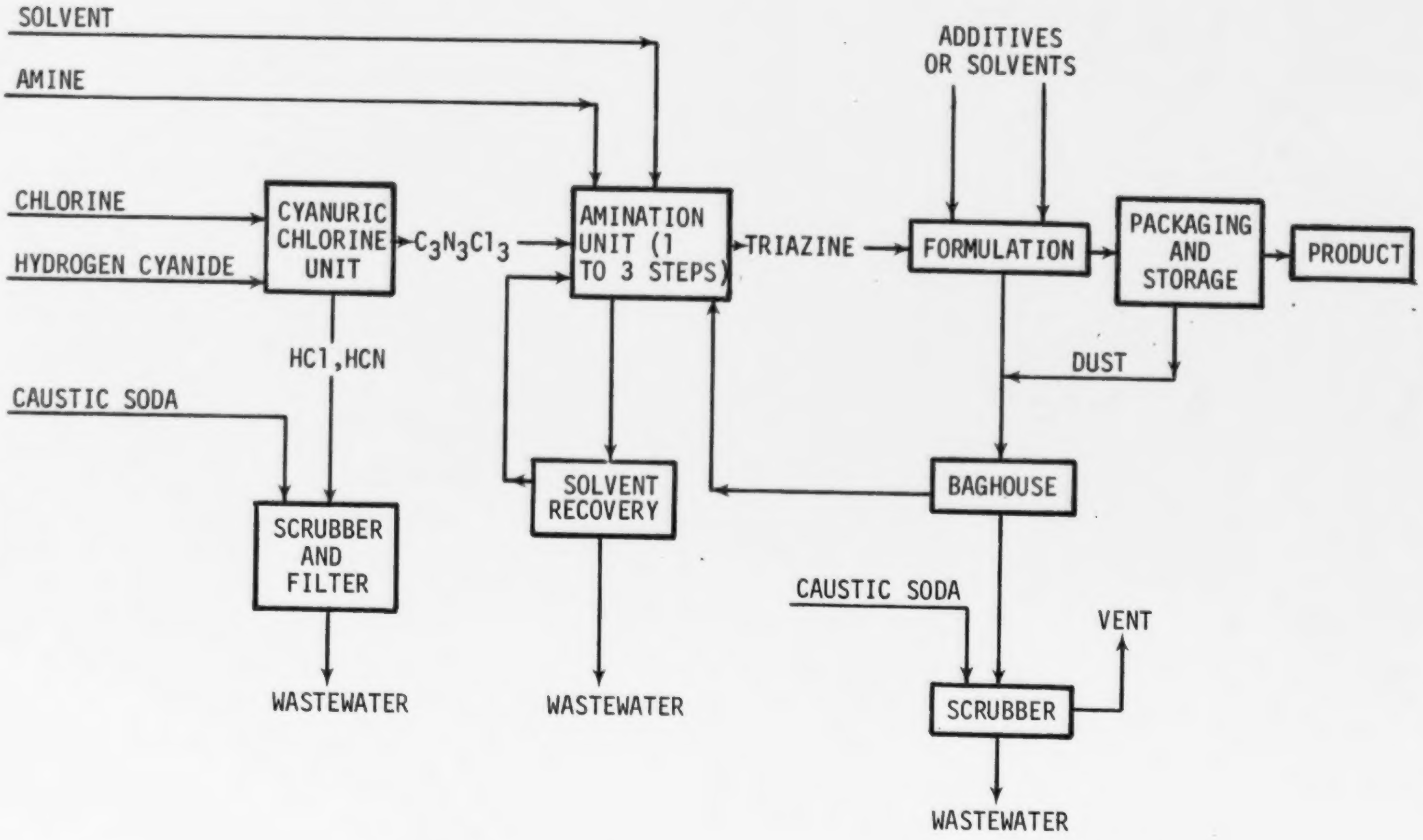
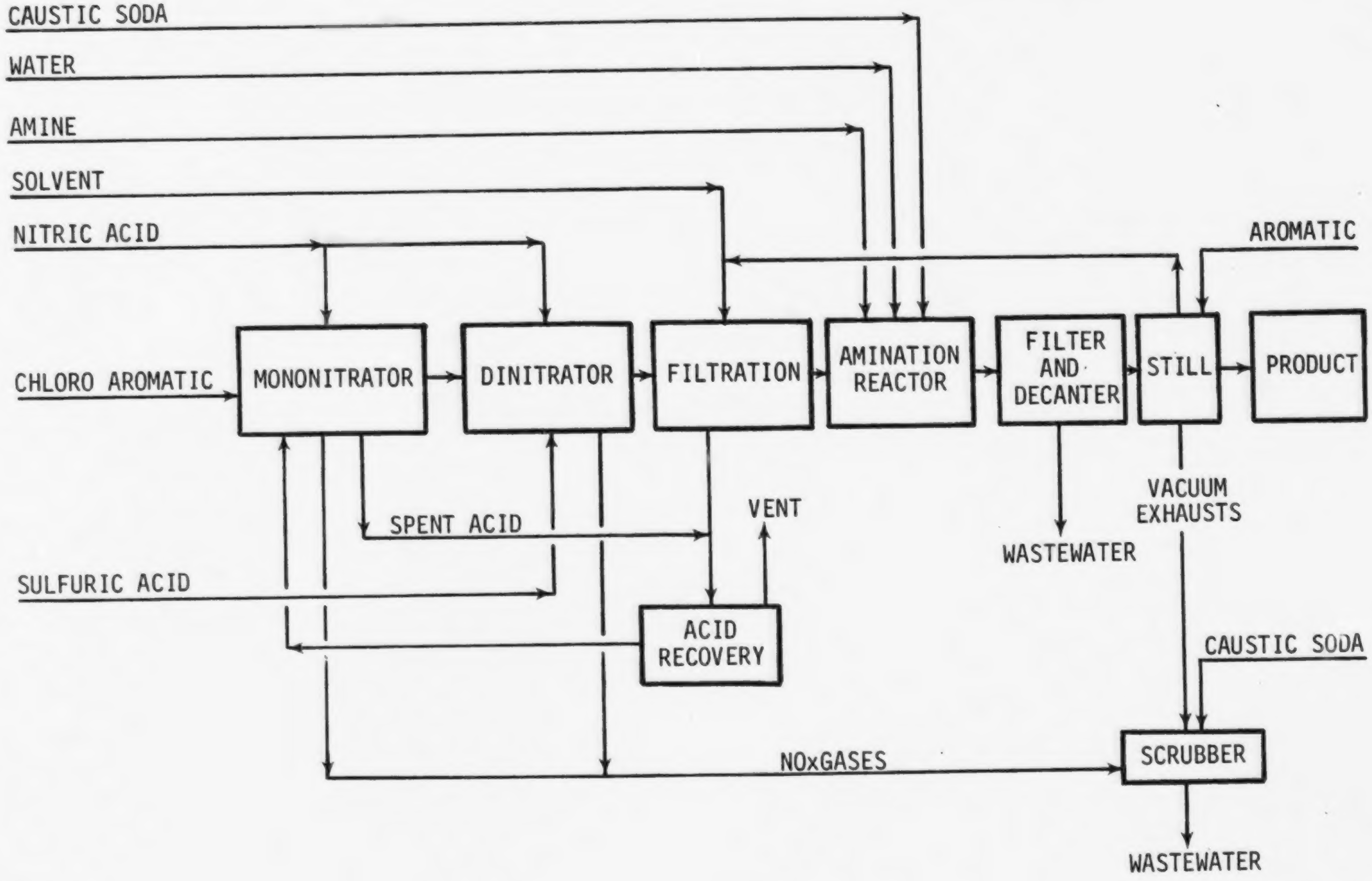

SOLVENT
AMINE
CHLORINE
HYDROGEN CYANIDE
CYANURIC CHLORINE UNIT
$C_3N_3Cl_3$
HCl,HCN
CAUSTIC SODA
SCRUBBER AND FILTER
WASTEWATER
AMINATION UNIT (1 TO 3 STEPS)
SOLVENT RECOVERY
WASTEWATER
TRIAZINE
ADDITIVES OR SOLVENTS
FORMULATION
PACKAGING AND STORAGE
PRODUCT
DUST
BAGHOUSE
CAUSTIC SODA
SCRUBBER
VENT
WASTEWATER

FIGURE III-16

GENERAL PROCESS FLOW DIAGRAM FOR NITRO-TYPE PESTICIDES


CAUSTIC SODA
WATER
AMINE
SOLVENT
NITRIC ACID
CHLORO AROMATIC
SULFURIC ACID
MONONITRATOR
DINITRATOR
FILTRATION
AMINATION REACTOR
FILTER AND DECANTER
STILL
PRODUCT
AROMATIC
SPENT ACID
VENT
ACID RECOVERY
WASTEWATER
VACUUM EXHAUSTS
CAUSTIC SODA
NOxGASES
SCRUBBER
WASTEWATER

cooled to settle out spent acid, which can be recovered and recycled. Oxides of nitrogen are vented and caustic scrubbed. The mono-nitrated product is then charged continuously to another nitrater containing 100 percent sulfuric acid and fuming nitric acid at an elevated temperature.

The dinitro product is then cooled and filtered (the spent acid liquor is recoverable), the cake is washed with water, and the resulting wash water is sent to the waste water treatment plant.

The dinitro compound is then dissolved in an appropriate solvent and added to the amination reactor with water and soda ash. An amine is then reacted with the dinitro compound. The crude product is passed through a filter press and decanter and finally vacuum distilled. The salt-water layer from the decanter is discharged for treatment. The solvent fraction can be recycled to the reactor, and vacuum exhausts are caustic scrubbed. Still bottoms are generally incinerated.

In summary, waste waters generated during the production of the nitro family of pesticides are:

1. Aqueous wastes from the filter and the decanting system
2. Distillation vacuum exhaust scrubber wastes
3. Caustic scrubber waste waters
4. Periodic kettle cleanout wastes
5. Production area washdowns

Subcategory 2--Metallo-Organic Pesticides

The metallo-organic group of pesticides includes the organic arsenicals and the dithiocarbamate metal complexes. A discussion of their manufacture and waste water sources is also applicable to the production of other compounds in this group.

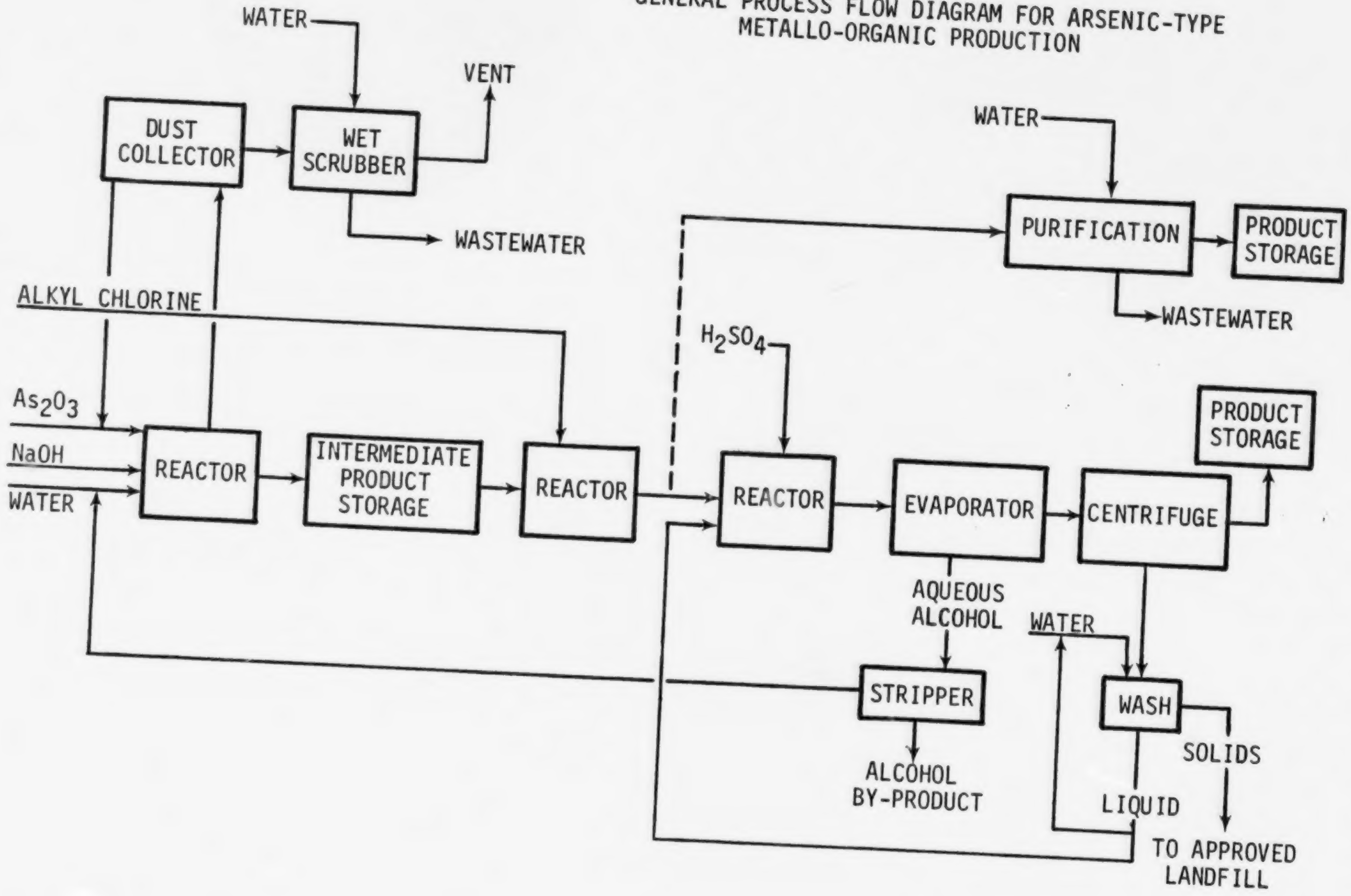
Monosodium methanearsenate (MSMA) is the most widely produced of the group of organo-arsenic herbicides (estimated production in 1972 was 24 million pounds) that also includes the octyl- and dodecyl-ammonium salts, the disodium salt (DSMA), and cacodylic acid (dimethylarsenic acid). DSMA can serve as an intermediate in the manufacture of all the others.

The process is described by the production and waste schematic flow diagram presented in Figure III-17.

The first step of the process is performed in a separate, dedicated building. The drums of arsenic tri-oxide are opened in an air-evacuated chamber and automatically dumped into 50 percent

FIGURE III-17

GENERAL PROCESS FLOW DIAGRAM FOR ARSENIC-TYPE METALLO-ORGANIC PRODUCTION


WATER
DUST COLLECTOR
WET SCRUBBER
VENT
WASTEWATER
ALKYL CHLORINE
As_2O_3
NaOH
WATER
REACTOR
INTERMEDIATE PRODUCT STORAGE
REACTOR
H_2SO_4
REACTOR
EVAPORATOR
CENTRIFUGE
PRODUCT STORAGE
WATER
PURIFICATION
PRODUCT STORAGE
WASTEWATER
AQUEOUS ALCOHOL
STRIPPER
ALCOHOL BY-PRODUCT
WATER
WASH
SOLIDS
LIQUID
TO APPROVED LANDFILL

caustic soda. A dust collection system is employed. The drums are carefully washed with water, the wash water is added to the reaction mixture, and the drums are crushed and sold as scrap metal. The intermediate sodium arsenite is obtained as a 25 percent solution and is stored in large tanks prior to further reaction. In the next step, the 25 percent sodium arsenite is treated with methyl chloride to give the disodium salt, DSMA. DSMA can be sold as a herbicide; however, it is more generally converted to the monosodium arsenate, MSMA, which has more favorable application properties.

In order to obtain MSMA, the solution is partially acidified with sulfuric acid and the resulting solution concentrated by evaporation. As the aqueous solution is being concentrated, a mixture of sodium sulfate and sodium chloride precipitates out (about 0.5 kg per 100 kg of active ingredient). These salts are a troublesome disposal problem because they are contaminated with arsenic. The salts are removed by centrifugation, washed in a multi-stage, counter-current washing cycle, and then disposed of in an approved landfill.

Methanol, a side product of methyl chloride hydrolysis, can be recovered and reused. In addition, recovered water is recycled.

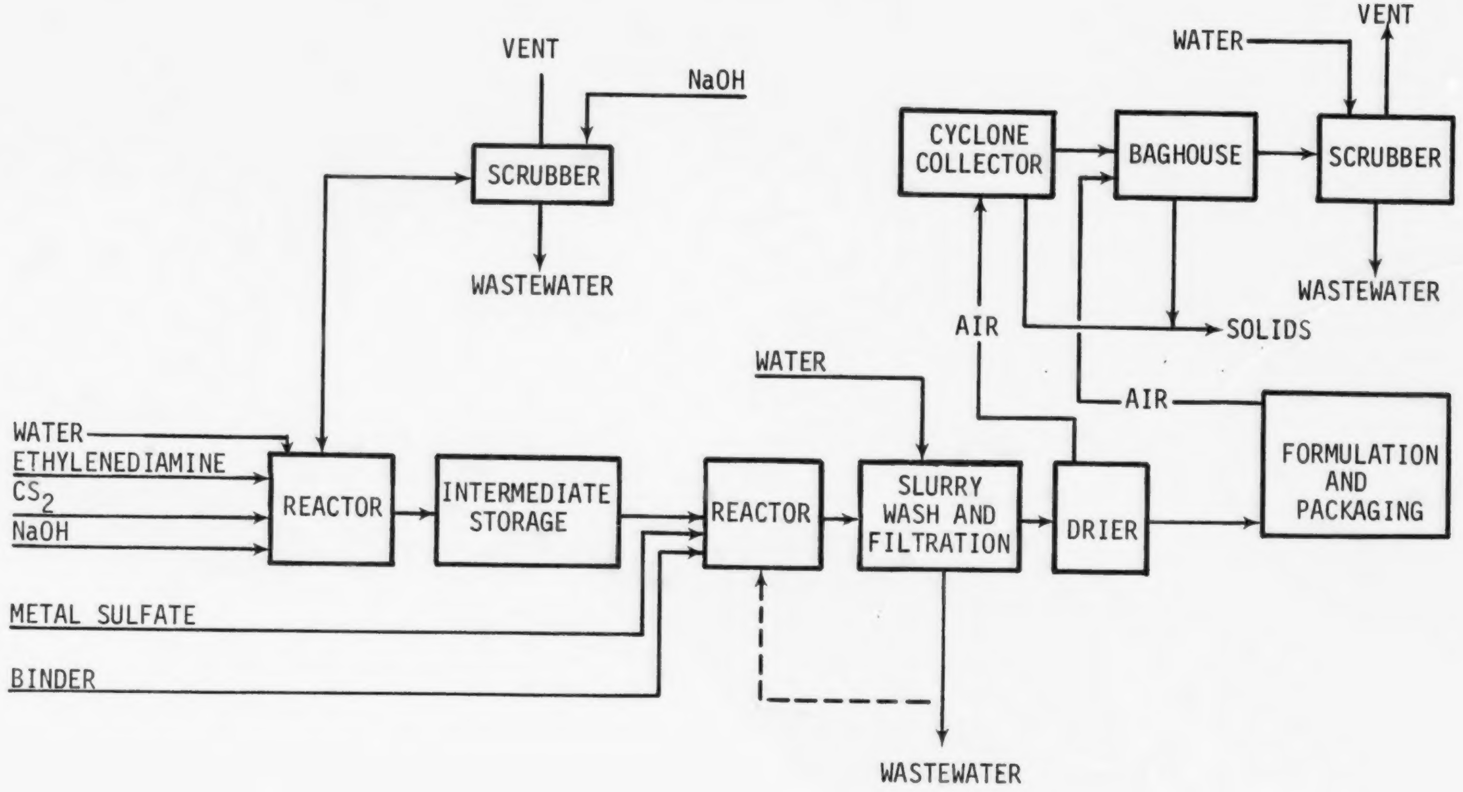
The products are formulated on site as solutions (for example, 48 percent (6 lb A.I./gal) and 58 percent (8 lb A.I./gal) and shipped in 1 to 30-gallon containers.

Figure III-18 is a typical process and waste generation schematic flow diagram for the production of ethylene bisdithiocarbamate metal complexes. Raw materials include carbon disulfide, ethylene diamine and sodium hydroxide (50 percent). These materials are first reacted in a stainless steel, cooled vessel. The exothermic reaction is controlled by the feed rate. Excess carbon disulfide is distilled, collected, and eventually recycled to the reactor. The sodium hydroxide addition controls pH. The resulting concentrated Nabam intermediate solution is reacted (within 24 hours) with a sulfate, and the desired metal organic complex is precipitated. The slurry is water washed to remove sodium sulfate and then dried to less than 1 percent water content. Process by-products include sodium sulfate and small amounts of carbon disulfide and sodium hydroxide.

Air emissions are controlled by cyclone collectors, bag filters, and scrubbers. The small amount of hydrogen sulfide from process vents is caustic scrubbed before release to the atmosphere. The liquid waste streams contain primarily salt.

FIGURE III-18

GENERAL PROCESS FLOW DIAGRAM FOR CERTAIN DITHIOCARBAMATE METALLO-ORGANIC PRODUCTION


VENT
NaOH
SCRUBBER
WASTEWATER
WATER
ETHYLENEDIAMINE
CS_2
NaOH
REACTOR
INTERMEDIATE STORAGE
METAL SULFATE
BINDER
REACTOR
WATER
SLURRY WASH AND FILTRATION
WASTEWATER
DRIER
AIR
CYCLONE COLLECTOR
BAGHOUSE
WATER
VENT
SCRUBBER
WASTEWATER
SOLIDS
AIR
FORMULATION AND PACKAGING

In summary, waste waters generated in the preparation of metallo-organics are from the following areas:

1. Spillage from drum washing operations
2. Washwater from product purification steps
3. Scrub water from vent gas scrubber unit
4. Process waste water
5. Area washdowns
6. Equipment cleanout wastes.

Subcategory 3--Formulators and Packagers

Pesticide formulations can be classified as liquids, granules, dusts and powders. There are approximately 3400 formulation plants registered with the Agency.

The scale on which pesticides are produced covers a broad range. Undoubtedly, many of the small firms, having only one product registration, produce only a few hundred pounds of formulated pesticides each year. At least one plant that operated in the range of 100,000,000 pounds of formulated product per year has been identified. The bulk of pesticide formulations, however, is apparently produced by independent formulators operating in the 20,000,000 to 40,000,000 pounds per year range.

Formulation Processes

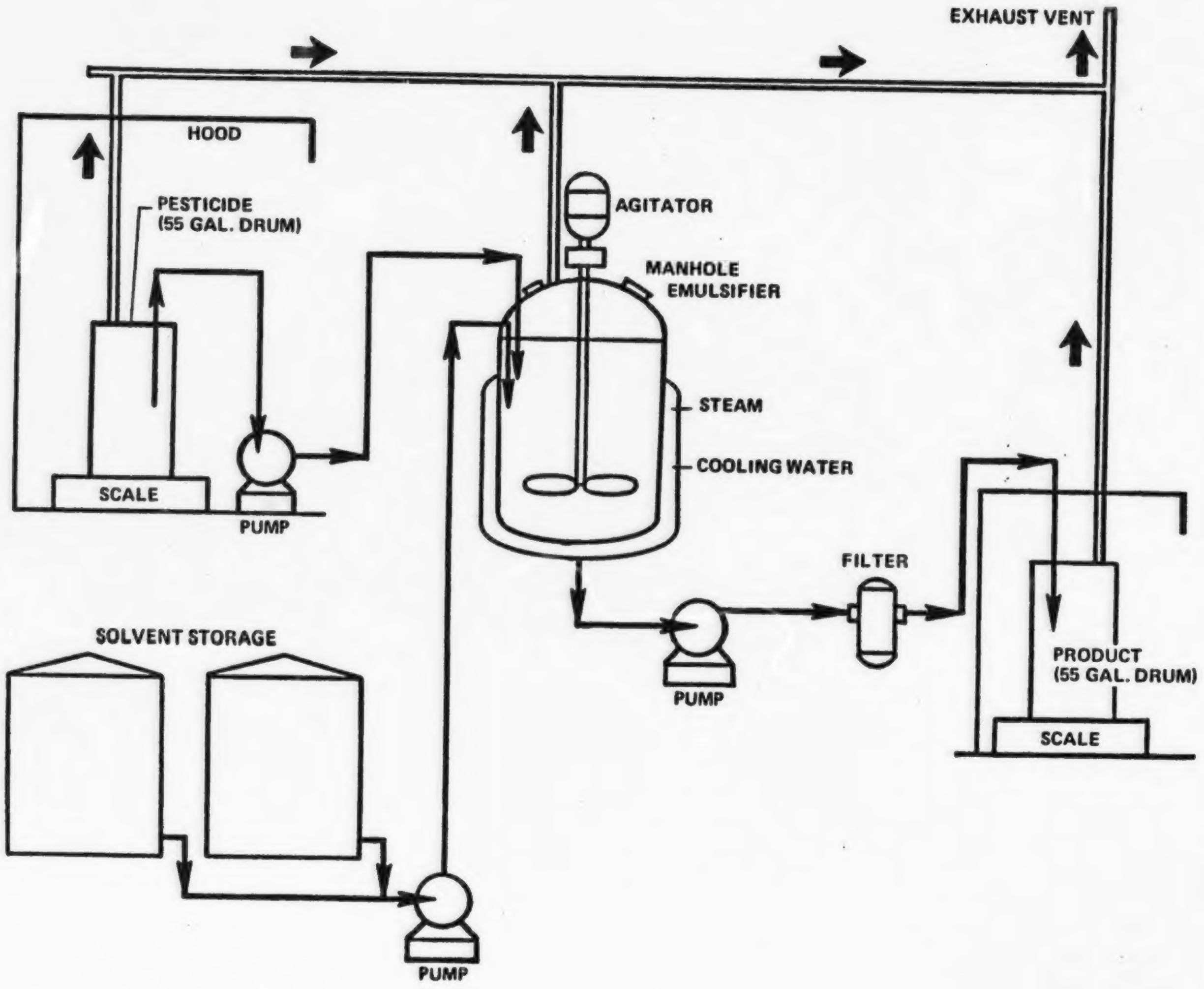
Most pesticides are formulated in mixing equipment that is used only for pesticide formulations. The most important unit operations involved are dry mixing and grinding of solids, dissolving solids, and blending. Formulation systems are virtually all batch mixing operations. Formulation units may be completely enclosed within a building or may be in the open, depending primarily on the geographical location of the plant.

Individual formulation units are normally not highly sophisticated systems. Rather, they are comparatively uncomplicated batch-blending systems that are designed to meet the requirements of a given company, location, rate of production, and available equipment. Production units representative of the liquid and solid formulation equipment in use are described in the following subsections.

Liquid Formulation Units: A typical liquid unit is depicted in Figure III-19. Technical grade pesticide is usually stored in its original shipping container in the warehouse section of the plant until it is needed. When technical material is received in bulk, however, it is transferred to holding tanks for storage.

FIGURE III-19

LIQUID FORMULATION UNIT


EXHAUST VENT
HOOD
PESTICIDE
(55 GAL. DRUM)
SCALE
PUMP
AGITATOR
MANHOLE
EMULSIFIER
STEAM
COOLING WATER
FILTER
PUMP
PRODUCT
(55 GAL. DRUM)
SCALE
SOLVENT STORAGE
PUMP

Batch-mixing tanks are frequently open-top vessels with a standard agitator. The mix tank may or may not be equipped with a heating/cooling system. When solid technical material is to be used, a melt tank is required before this material is added to the mix tank. Solvents are normally stored in bulk tanks. an exact quantity of an appropriate solvent is either metered into the mix tank, or determined by measuring the tank level. Necessary blending agents (emulsifiers, synergists, etc.) are added directly from the mix tank. The formulated material is frequently pumped to a holding tank before being put into containers for shipment. Before being packaged, many liquid formulations must be filtered by conventional cartridge filters or equivalent polishing filters.

Air pollution control equipment used on liquid formulation units typically involves an exhaust system at all potential sources of emission. Storage and holding tanks, mix tanks, and container--filling lines are normally provided with an exhaust connection or hood to remove any vapors. The exhaust from the system normally discharges to a scrubber system or to the atmosphere.

Dusts and Wettable Powders: Dusts and powders are manufactured by mixing the technical material with the appropriate inert carrier, and grinding this mixture to obtain the correct particle size. Mixing can be affected by a number of rotary or ribbon blender type mixers. See Figure III-20.

Particulate emissions from grinding and blending processes can be most efficiently controlled by baghouse systems. Vents from feed hoppers, crushers, pulverizers, blenders, mills, and cyclones are typically routed to baghouses for product recovery. This method is preferrable to the use of wet scrubbers, however even scrubber effluent can be largely eliminated by recirculation.

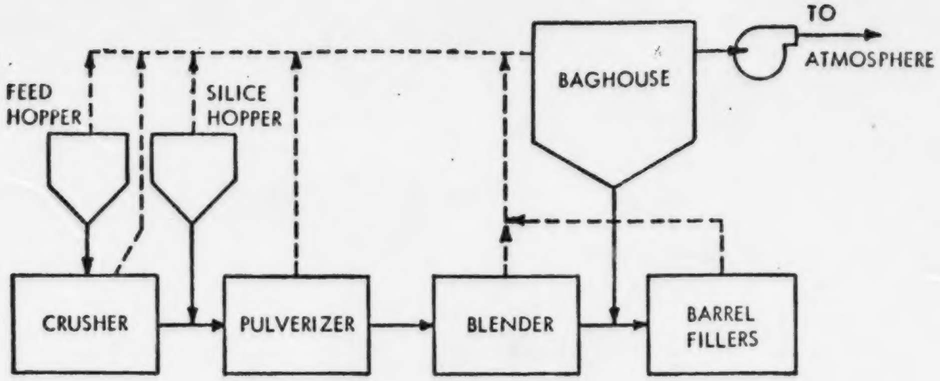
Granules: Granules are formulated in systems similar to the mixing sections of dust plants. The active ingredient is adsorbed onto a sized, granular carrier such as clay or a botanical material. This is accomplished in various capacity mixers that generally resemble cement mixers.

If the technical material is a liquid, it can be sprayed directly onto the granules. Solid technical material is usually melted or dissolved in a solvent in order to provide adequate dispersion on the granules. The last step in the formulation process, prior to intermediate storage before packaging, is screening to remove fines.

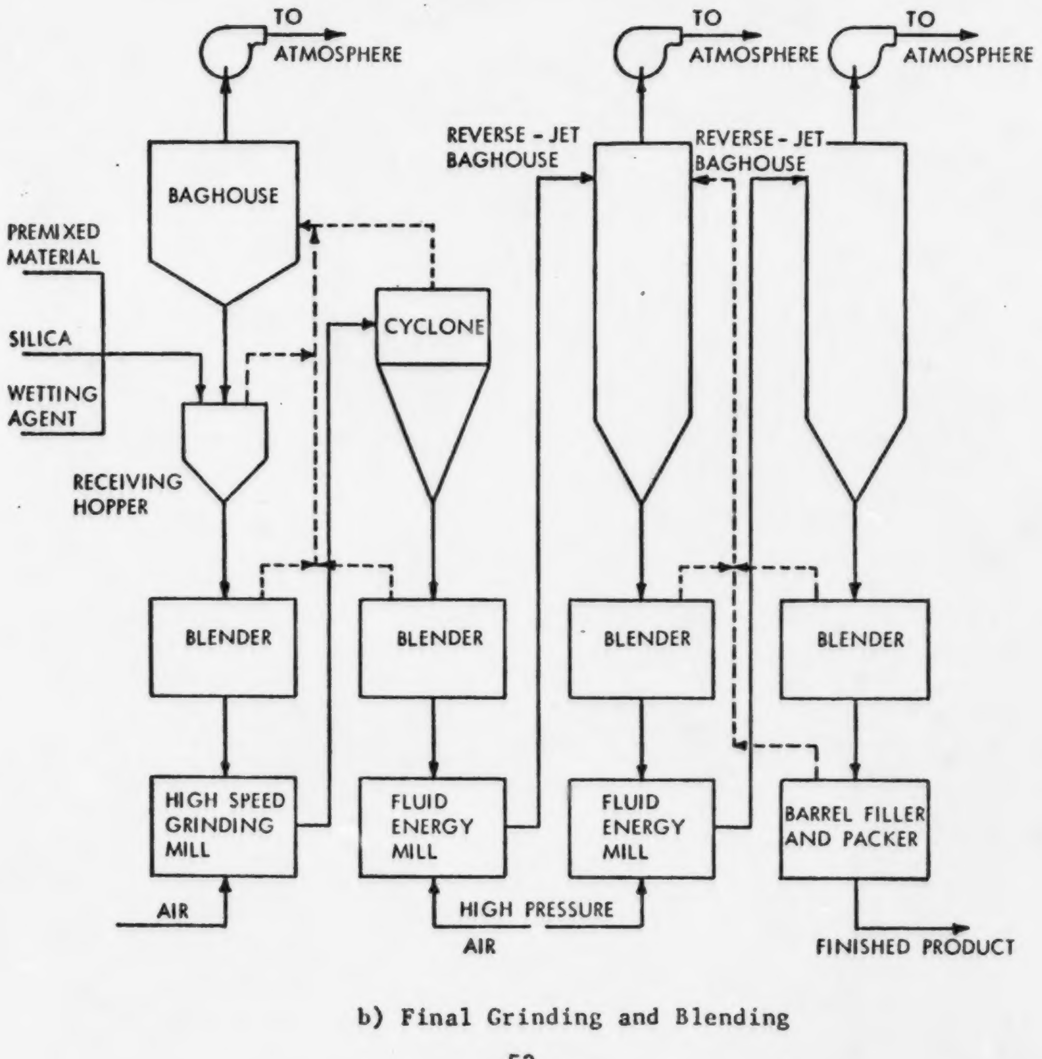
Packaging and Storage: The last operation conducted at the formulation plant is packaging the finished pesticide into a

Figure III-20

Dry Formulation Unit


TO
ATMOSPHERE
BAGHOUSE
FEED
HOPPER
SILICE
HOPPER
CRUSHER
PULVERIZER
BLENDER
BARREL
FILLERS

a) Premix Grinding


TO
ATMOSPHERE
TO
ATMOSPHERE
TO
ATMOSPHERE
REVERSE - JET
BAGHOUSE
REVERSE - JET
BAGHOUSE
BAGHOUSE
PREMIXED
MATERIAL
SILICA
WETTING
AGENT
CYCLONE
RECEIVING
HOPPER
BLENDER
BLENDER
BLENDER
BLENDER
HIGH SPEED
GRINDING
MILL
FLUID
ENERGY
MILL
FLUID
ENERGY
MILL
BARREL FILLER
AND PACKER
AIR
HIGH PRESSURE
AIR
FINISHED PRODUCT

b) Final Grinding and Blending

marketable container. This is usually done in conventional filling and packaging units. Frequently, the same liquid filling line is used to fill products from several formulation units; the filling and packaging line is simply moved from one formulation unit to another. Packages of almost every size and type are used, including 1, 2, and 5-gallon cans, 30 and 55-gallon drums, glass bottles, bags, cartons, and plastic jugs.

On-site storage, as a general rule, is minimized. The storage facility is very often a building completely separate from the actual formulation and filling operation. In almost all cases, the storage area is at least located in a part of the building separate from the formulation units in order to avoid contamination and other problems. Technical material, except for bulk shipments, is usually stored in a special section of the product storage area.

In formulation and packaging plants, waste waters can be potentially generated at several sources. These sources and operations are discussed in the following subsection.

Miscellaneous Plant Operations

For housekeeping purposes, most formulators clean buildings which house formulation units on a routine basis. Prior to washdown, as much dust, dirt, etc., as possible is swept and vacuumed up. The waste water from the building washdown is normally contained within the building, and is disposed of in whatever manner is used for other contaminated waste water. At least one plant had raised curbs around all floor drains and across all doorways to keep spills within the area. Absorbent compounds and vacuum sweepers are then used to collect the contaminants.

Water-scrubbing devices are often used to control emissions to the air. Most of these devices generate a waste water stream that may be contaminated with pesticidal materials. Although the quantity of water in the system is high, about 20 gallons per 1,000 cfm, water consumption is kept low by a recycle-sludge removal system. Effluent from air pollution control equipment should be disposed of with other contaminated waste water. One type of widely used air scrubber is the toro-clone separator, in which air is cleaned by centrifugal force.

A few formulation plants process used pesticide drums so that they can be sold to a drum reconditioner or reused by the formulator for appropriate products, or simply to decontaminate the drums before they are disposed of. Drum-washing procedures range from a single rinse with a small volume of caustic solution or water to complete decontamination and reconditioning processes. Wastewaters from drum-washing operations are contained within the processing area and treated with other processing waste waters.

Most of the larger formulation plants have some type of control laboratory on the plant site. Wastewater from the control laboratories, relative to the production operations, can range from an insignificantly small, slightly contaminated stream to a rather concentrated source of contamination. In many cases, this stream can be discharged into the sanitary waste or municipal treatment system. Larger, more highly contaminated streams, however, must be treated along with other contaminated waste waters.

The major source of contaminated waste water from pesticide formulation plants is equipment cleanup. Formulation lines, including filling equipment, must be cleaned out periodically to prevent cross-contamination of one product with another, and occasionally that needed maintenance may be performed. When possible, equipment is washed with formula solvent. The collected solvent can be used in the next formulation of the same product.

Liquid formulation lines are cleaned out most frequently and generally require the most water. All parts of the system that potentially contain pesticidal ingredients must be washed. More than one rinsing of process vessels and lines is required to get the system clean. As a general rule, the smaller the capacity of the line, the more critical cleanup becomes, in order to avoid cross contamination. Thus, large volumes of washwater are required, relative to production quantity, for smaller units.

Granule, as well as dust and powder lines, also require cleanup. Liquid washouts are generally required, however, only in that portion of the units where liquids are normally present, i.e., the active ingredient pumping system, scales, and lines. The remainder of these production units can normally be cleaned out by "dry washing" with an inert material, such as clay.

Spills of technical material or material in process are normally absorbed on sand or clay, and are disposed of with other potentially toxic solid wastes in a Class-1 landfill. If the spill area is washed down, the resultant waste water should be disposed of with the other contaminated waste waters.

Natural runoff at formulating and packaging plants, if not properly handled, can become a major factor in the operation of waste water systems simply because of the relatively high flow and the fact that normal plant waste water volumes are generally extremely low. Isolation of runoff from any contaminated process areas or waste waters, however, eliminates its potential for becoming significantly contaminated with pesticides. Uncontaminated runoff is usually allowed to drain naturally from the plant site.

In some plants, the formulation units, filling lines, and storage areas are located in the open. The runoff from these potentially contaminated areas, as a rule, cannot be assumed to be free of pollutants and should not be allowed to discharge directly from the plant site.

In summary, waste waters generated at formulator and packaging plants are:

1. Formulation equipment cleanup
2. Spill washdown
3. Drum washing
4. Air pollution control devices
5. Area runoff

SECTION IV

INDUSTRIAL SUBCATEGORIZATION

The purpose of subcategorization is to account for differences in technological achievement, economic impact and other consequences when applying limitations to a category. The rationale for subcategorization of the pesticides category assignment can be based on factors such as (1) composition and/or quantity of waste produced; (2) feasibility and effectiveness of treatment; and (3) the cost of treatment. While mitigating factors such as plant age and size also affect to a lesser extent the composition and quantity of waste produced, the important differences were in waste quantity, treatability, engineering, and cost. The discussion that follows considers these factors in more detail.

Manufacturing Processes

Pesticide plants manufacturing active ingredient products employ a number of unit processes in series. The principal processes utilized include chemical synthesis, separation, recovery, purification, and product finishing.

Chemical syntheses include chlorination, alkylation, nitration, as well as many other reactions. Separation processes include filtration, decantation, extraction and centrifugation. Recovery and purification are utilized to reclaim solvents or excess reactants as well as to purify intermediates and final products. Evaporation and distillation, are also common. Product finishing includes operations such as blending, dilution, pelletizing, packaging, and canning.

Since these diverse processes are used by all sectors in the synthesis of active ingredients, the type of manufacturing process alone is not a comprehensive basis for subcategory assignment.

A significant process difference does exist between active ingredient manufacturing operations and formulating and packaging. Besides the process differences, less water is used in formulating and packaging. Less (if any) wastes are generated, and less treatment is needed.

Product

There are several ways to group pesticides. For example, the November 1, 1976, regulation for this industry utilized chemical structure to differentiate halogenated organic, organo-phosphorus, organo-nitrogen, and metallo-organic products. Some of these groups were further divided, such as the s-triazine pesticides (exempted from regulation pending further study).

A listing of major pesticide chemicals covered in this regulation is presented in Table X-1. As this table shows, many pesticides contain a number of elements such as halogens, phosphorus, nitrogen, sulfur, and oxygen. Investigation revealed the disadvantage in establishing separate subcategories for halogen, phosphorus, and nitrogen pesticides. Certain products contained combinations of these elements, and thus could only be assigned to subcategories by greatest similarity to that subcategory. In addition, many plants produced products in more than one of these subcategories.

It was concluded that placing non-metallic halogenated, phosphorus, and nitrogen compounds in one group would result in a more logical and equitable basis for subcategorization. This conclusion is supported by the nature and treatability of wastes generated. Separate subcategories are maintained for metallo-organic pesticide chemicals and pesticide chemicals formulating and packaging which do not need to discharge process waste waters.

Raw Materials

The raw materials used in the pesticide chemicals industry are specific to the product being manufactured. Within narrow ranges of quality and purity, variations in raw material do have a significant impact on the quantities of waste products generated. However, the waste loads are so diverse that no groupings (subcategorization scheme) could be made, (See Section V). The quantity and composition of wastes generated is also determined by whether the raw materials are purchased or produced captively. Irrespective of raw material source, the waste waters were found to be amenable to pesticide removal, equalization and biological treatment. Thus, the selection of raw materials is not a significant factor on which to base further subcategorization.

Plant Size

There are more than 100 plants in the United States engaged in the production of pesticide active ingredients, and as many as 3,000 facilities formulating the active ingredients into final products. These are marketed as liquids, dusts, and packaged aerosols. In order to determine whether plant size is a factor in subcategorization, the raw waste loads (kg/kkg) for each plant were plotted versus plant production (1000 lb/day). No uniform correlation could be made. Plant size should also not affect the applicability or performance of treatment technologies as outlined in later sections of this document, but may affect the cost of treatment facilities and cost per unit of production. Accordingly, plant size is not considered as a major criterion for subcategorization, but has been taken into consideration in the cost estimates.

Plant Age

Pesticide plants are relatively new, commissioned predominantly in the post-World War II period, and the general processing technologies have not changed appreciably. The use of different processing modes, such as batch, semi-continuous, and continuous, depends on product type, inherent process requirements, and economies of scale. The individual process lines are modified as needed for product or process changes, but plant age is not reflective of existing process systems at any given plant site since new processes are normally installed at old and new facilities alike. Therefore, it is concluded that plant age is not a significant factor for subcategorization.

Plant Location

As indicated by Figure III-1, pesticide chemicals manufacturing plants are distributed throughout the United States although they are primarily concentrated in the eastern and southern regions. Based on analyses of existing data presented in recent studies and the results of plant visits to the southern, midwestern, and northern geographical areas of the country, plant location has little effect on the quality or quantity of the waste water generated. Geographic location, however, can influence the performance of aerated and stabilization lagoons or evaporation basins. Poor performance problems (temperature related) can be overcome by adequate sizing or selection of alternative processes, such as activated sludge. Moisture related problems can be overcome by coverings.

Most pesticide plants are relatively new, and the trend in the chemical industry is to locate outside urban areas. Those plants that are located in urban areas tend to occupy and own less land, with the result that land costs for treatment facilities are higher than for plants located in rural areas. Urban plants have alternative technologies available to them which require less land area, and achieve the same results.

Taking the above points into account, it can be said that, other than costs associated with land availability, plant location is not a significant factor for further subcategorization.

Housekeeping

Housekeeping practices vary within the category. However, they are influenced more by the philosophy of the company and the personnel involved than by the manufacturing process or product mix. In many cases, plants with comprehensive treatment facilities or a history of good treatment also exhibit good housekeeping techniques. This practice is founded on necessity and experience which dictate that good treatment requires good housekeeping.

In view of these findings it is concluded that housekeeping is not a reasonable factor for subcategorization.

Air Pollution Control Equipment

Air pollution control problems and equipment utilized are not generally unique to different segments of this point source category. Vapors and toxic gas fumes are frequently incinerated. Particulates can be removed by either baghouses or wet scrubbing devices. In all cases, the wastes produced by air pollution control devices are readily treatable for all subcategories and do not serve as a basis for subcategorization.

Nature of the Wastes Generated

The quality and quantity of the wastes generated by the pesticides chemicals industry are discussed fully in Section V. The nature of the wastes generated is a supporting basis for subcategorization. As Figures V-1 through V-6 demonstrate, there are no consistent differences in raw waste loads among the various chemical families of the organic pesticide chemicals industry. However, the metallo-organic manufacturers and formulators/packagers generate smaller volumes, if any at all. The nature of wastes generated is thus a supporting factor for subcategorization.

Treatability of Wastewaters

The waste waters generated from the manufacture of organic pesticide chemicals are currently being treated by combinations of activated carbon or hydrolysis pesticide removal, equalization, and biological systems. Activated carbon was previously believed to be used only for halogenated pesticides. It is now known that it is frequently used in the treatment of nitrogen based pesticides and is also applicable to phosphorus based pesticides. No end-of-pipe treatment is required for the metallo-organic pesticides covered in this document. Recycle techniques and concentrating waste streams and hauling them to approved landfills have proven to be an economically sound technique, resulting in no discharge of process waste waters. The low flows generated by formulating and packaging can be suitably controlled by recycle, reuse, or evaporation. Many formulating operations generate no waste water and therefore require no treatment.

Summary of Considerations

For the purpose of establishing effluent limitations it was concluded that the pesticide chemicals point source category should be grouped into three subcategories. This subcategorization is based on distinct differences in the volume of wastes generated, treatability and manufacturing process.

The pesticide chemicals manufacturing point source category has been grouped into the following subcategories:

1. Organic pesticide chemicals manufacturing.
2. Metallo-organic pesticide chemicals manufacturing.
3. Pesticide chemicals formulating and packaging.

It should be made clear that the production operations so categorized occur in combinations at many plants and that it is possible for a given facility to be associated with all of the subcategories as well as with other chemical production. It is further recognized that many plants produce or use intermediate products. These factors are discussed in Section IX under "Factors to be Considered in Applying Effluent Guidelines."

SECTION V

WASTEWATER CHARACTERISTICS

The purpose of this section is to define the waste water quality and quantity for plants in those subcategories identified in Section IV. Based on these data, design criteria are developed for the model treatment technologies presented in Section VII. The raw waste load data are thus used only for cost analyses, and not in the development of effluent guidelines. Under no conditions should the raw waste load design criteria be construed to be exemplary or used as a basis for pretreatment guidelines for industrial discharges into publicly owned treatment works.

The term raw waste load, as utilized in this document, is defined as the quantity of a pollutant in waste water prior to a treatment process, whether the process is carbon adsorption, hydrolysis, or biological treatment. It is normally expressed in terms of mass (weight) units per day or per production unit. In several cases plants are producing pesticides, intermediates, and nonpesticide products concurrently. If monitoring at these plants was insufficient to separate the waste water contribution due to the pesticide portion, then the mass unit loading was divided by the total plant production. A discussion of the interpretation of effluent guidelines based on this assumption is presented in Section IX.

Due to the volume of information available, Subcategory 1 data remain grouped by chemical structure (i.e., halogenated, phosphorus, or nitrogen). In the latter part of this section, however, design criteria are developed using all available data for the subcategory as defined in Section IV.

Subcategory 1--Organic Pesticide Chemicals

Process waste waters from Subcategory 1 may result from the following steps: decanting, distillation, stripping, extraction/precipitation, and purification. High organic and solids loadings may be caused by equipment cleanout, area washdowns, accidental spillage, or poor operation. Caustic scrubbers and contact cooling may contribute significantly to total flow. A summary of sources of wastes from processing units utilized in the manufacturing of organic pesticides unit operations is contained in Table V-1. A summary of raw waste loads for organic pesticide manufacturers is presented in Table V-2.

TABLE V-1

SUMMARY OF POTENTIAL PROCESS--ASSOCIATED WASTE WATER SOURCES
FROM ORGANIC PESTICIDE PRODUCTION

Processing Unit	Source	Nature of Waste Water Contaminants
Acid recovery unit	Liquid wastes	High pH
Air pollution control equipment	Aqueous suspension	High suspended solids, relatively low dissolved organics and solids
All plant areas	Run-off, area washdowns	Intermittent flow, low organics, variable pH, variable suspended solids, variable salt content
Caustic scrubber	Vented process gases Spent caustic solu-	High pH, possible by-product HCN, high flow, low organics, low organics, high dissolved solids
Centrifuges	Mother liquour	High organics, generally toxic
Crystallizer, dryer, flakers, prilling	Dusts, mists	High toxic organics, high total suspended solids
Decanter	Aqueous layer	High salt content, dissolved organics, separable organic sludge, NH3-N and TKN
	Organic layer	High organic, low dissolved organic salt or sludge
Distillation tower	Distillation residues and tars	High organic, low solubility in water, frequently high chlorine content
Dust wet scrubbers	Aqueous suspension	High total suspended solids, high toxic organics
Extractor/precipitator	Aqueous wastes	High dissolved and suspended organics, high pH and frequently high dissolved solids and high NH3-N
Filtration	Filtrate	High pH, dissolved organics and dissolved solids
Hydrolyzer/extractor	Aqueous layer	High pH, high COD, high dissolved solids, organic sludge
Incinerator exhaust scrubbers	Scrubber water	Dissolved inorganics, high pH
Intermediate product neutralizer	Spillage	Low waste loss, pH variable, high organic, high dissolved solids
Intermediate product purification	Neutralized aqueous	pH, high dissolved organics and dissolved solids
Intermediate product reactor	Reaction product	Intermittent flow, high dissolved solids, pH variable, organic content variable

TABLE V-1 (Continued)

Processing Unit	Source	Nature of Waste Water Contaminants
Nitrators	Vent gas scrubbers	High nitrates, dissolved solids and high pH
Overheads collector	Dust, mists, vapors	High toxic organics, high total suspended solids
Product recovery	Aqueous wastes	High toxic organics, low flow
Product washers	Neutralized aqueous	Organic product loss, high pH, high dissolved solids, intermittent flow
Purification	Aqueous wastes	High dissolved organics and solids
Reactors	Clean out rinse water, wasted solvent	High dissolved solids and organics. Variable pH, intermittent flow
Scrubber from cyanuric chloride unit	Scrubber and filter water	High pH. Cyanide waste water, low organics, high dissolved solids
Settling tank	Spent acid	Low pH, intermittent flow, moderate organic content
Solvent recovery	Aqueous layer	High salt content, high pH, intermittent flow rate, toxic components, some "intermediate" product
Solvent strippers	Stripper clean-out water	High organics, low flow
Vacuum jets	Vacuumed gases	Low organic, generally acidic
Wet scrubber	Acidic solution	Low pH, moderately high flow rate, little organic wastes

TABLE V-2

RAW WASTE LOADS
ORGANIC PESTICIDE CHEMICALS MANUFACTURERS
SUBCATEGORY 1

Plant	Product(s)	L/Kkg	FLOW Gal/1000 lb	(n)	BOD kg/Kkg	BOD mg/l	(n)	COD kg/Kkg	COD mg/l	(n)	TSS kg/Kkg	TSS mg/l	(n)	PESTICIDES kg/Kkg	PESTICIDES mg/l	(n)	Source of Data
3	1	7250	869	(E)	--	--	---	--	--	---	65.2(E)	9000	(1)	0.159	2.2	(E)	(a)
4	1	252	3	(E)	--	--	---	--	--	---	--	--	---	---	N.D.	(E)	(b)
6	2,3,4,5	12800	1540	(5)	20.0	1630	(3)	70.3	5780	(5)	0.856	69	(5)	0.793	58.4	(5)	(c)
8	6,7	3150	377	(63)	--	--	---	18.3	5766	(11)	4.79	1510	(11)	--	--	---	(d)
	6,7	15100	1808	(E)	--	--	---	89.0	5900	(E)	36.4	2410	(E)	1.3	86.2	(3)	(e)
	6	4210	505	(25)	AI	AI	AI	4.73	881	(7)	1.93	360	(7)	0.0655	15.5	(25)	(f)
9	1	1760	211	(E)	--	--	---	--	--	---	--	--	---	0.001	0.4	(E)	(g)
12	8	1060	127	(E)	--	--	---	--	--	---	--	--	---	---	N.D.	(E)	(h)
18	1	3810	457	(E)	--	--	---	--	--	---	--	--	---	---	N.D.	(E)	(i)
19	9,10	64800	7770	(34)	5.98	92.0	(34)	30.4	429	(28)	--	--	---	--	--	---	(j)
20	11	976	117	(E)	44.1	45200	(6)	144	148000	(6)	1.42	1460	(6)	0.0144	14.8	(6)	(k)
	11	986	117	(E)	--	--	---	--	--	---	--	--	---	0.0177	18.2	(16)	(l)
21	12	75900	9100	(E)	498	6570	(E)	--	--	---	3.75	49	(E)	--	--	(E)	(m)
	12	50400	6040	(30)	211	3880	(30)	--	--	---	5.50	103	(30)	0.79	15.0	(30)	(n)
	17	17600	2110	(29)	204	9590	(29)	--	--	---	1.5	62.0	(29)	1.1	57.0	(29)	(s)
	17	22900	2740	(E)	337	14700	(E)	--	--	---	1.2	52.5	(E)	--	--	---	(t)
	37-45	46300	5550	(E)	38.5	832	(E)	--	--	---	--	--	---	--	--	---	(hh)
22	2,13	8060	976	(E)	62.9	7800	(E)	113	14000	(E)	0.19	24	(E)	16.1	2000	(E)	(o)
	2,13	8760	1050	(30)	62.9	7200	(30)	125	14300	(30)	1.92	220	(30)	--	--	---	(p)
	14	10000	1200	(E)	85.0	8500	(E)	160	16000	(E)	--	--	---	--	--	---	(q)
	18,19,20	2780	333	(E)	1.5	540	(E)	45.0	15200	(E)	--	--	---	--	--	---	(u)
	18,20	2780	333	(1)	--	--	---	36.5	13200	(1)	0.13	47	(1)	--	--	---	(v)
	46	10000	1200	(E)	24.5	2450	(E)	81.3	8120	(E)	1.81	181	(E)	--	--	---	(ii)
23	15,16	411000*	49200*	(150)	--	--	---	43.1	105	(150)	55.0	134	(150)	0.0127	0.031	(150)	(r)
	16	---	---	---	--	--	---	---	---	---	---	---	---	0.052	0.127	(150)	(r)
27	21	12600	1510	(12)	110	8730	(12)	180	14300	(12)	4.5	360	(12)	--	--	---	(w)
28	21/22	66200	7930	(8)	--	--	---	261	3940	(7)	9.32	141	(8)	--	--	---	(x)
	21	50400	6050	(61)	--	--	---	185	3670	(61)	--	--	---	0.235	4.66	(61)	(y)
	22	49500	5730	(31)	--	--	---	90.7	1830	(31)	--	--	---	0.454	9.17	(31)	(z)
29	5,7	12800	1530	(2)	--	--	---	79.0	6100	(2)	--	--	---	--	--	---	(aa)
32	24	107000	12900	(E)	--	--	---	333	3110	(E)	--	--	---	--	--	---	(bb)
	25	2660	319	(E)	--	--	---	107	40200	(E)	--	--	---	--	--	---	(bb)
	26	60500	7200	(E)	--	--	---	192	3150	(E)	--	--	---	--	--	---	(bb)
	27	10700	1285	(E)	--	--	---	96	8910	(E)	--	--	---	--	--	---	(bb)

Table V-2

Page 2 of 4 Pages

	28	5170	620	(E)	--	--	---	20	3850	(E)	--	--	---	--	--	---	(bb)
	29	62100	7440	(E)	--	--	---	192	3100	(E)	--	--	---	--	--	---	(bb)
	30	1670	200	(E)	--	--	---	70	4200	(E)	--	--	---	--	--	---	(bb)
	31	14700	1760	(E)	--	--	---	46	3150	(E)	--	--	---	--	--	---	(bb)
	25	31200	3740	(11)	--	--	---	661	21200	(11)	8/.7	2810	(11)	0.122	3.y	(39)	(cc)
	24-31	15300	1840	(31)	26.6	1750	(8)	105	6850	(31)	4.14	269	(21)	--	--	---	(dd)
	24-31	14200	1700	(28)	45.2	2780	(6)	118	7320	(28)	3.66	22/	(16)	--	--	---	(ee)
	47	13500	1620	(E)	--	--	---	64	4740	(E)	--	--	---	--	--	---	(jj)
	48	51600	6180	(E)	--	--	---	77	1480	(E)	--	--	---	--	--	---	(jj)
33	32	--	--	---	--	--	---	--	5090	(33)	--	43	(27)	--	--	---	(ff)
34	33	31400	3760	(E)	--	--	---	--	--	---	--	--	---	--	--	---	(gg)
	34	4500	540	(E)	--	--	---	--	--	---	--	--	---	--	--	---	(gg)
	35	21100	2530	(E)	--	--	---	--	--	---	--	--	---	--	--	---	(gg)
	36	1495	180	(E)	--	--	---	--	--	---	--	--	---	--	--	---	(gg)
	49	None	None	---	--	--	---	--	--	---	--	--	---	--	--	---	(kk)
36	37	32100	3850	(11)	3.73	116	(8)	31.5	981	(10)	4.1	128	(11)	2.54	79.0	(11)	(ll)
39	50,51,52	3470	416	(E)	--	--	---	83(A)	23900	(E)	--	--	---	--	--	---	(mm)
	53	6450	774	(E)	--	--	---	154	23900	(E)	--	--	---	--	--	---	(mm)
	54	19800	2370	(E)	--	--	---	4562(B)	231000	(E)	--	--	---	--	--	---	(mm)
	55	39300	4718	(E)	--	--	---	7688(B)	195000	(E)	--	--	---	--	--	---	(mm)
	56	1300	156	(E)	--	--	---	1582(B)	1220000	(E)	--	--	---	--	--	---	(mm)
	52	1560	187	(4)	1.55	995	(4)	12.9	8310	(4)	0.26	168	(4)	0.0175	11.3	(4)	(nn)
41	5/,58,59	23700	2845	(61)	24.6	1040	(24)	54.6	2300	(61)	0.528	22.2	(61)	1.51	63.6	(61)	(oo)
	57,58,59	31100	3730	(209)	50.3	1620	(118)	99.9	3050	(209)	--	--	---	4.26	103	(200)	(pp)
45	60	(C)	(C)	---	(C)	595	(3)	(C)	4750	(5)	(C)	68.6	(5)	(C)	218	(5)	(qq)
46	37	35300	4230	(98)	--	--	---	--	--	---	1.04	29.5	(98)	0.664	18.9	(98)	(rr)
48	61	--	--	---	58	--	(E)	97	--	(E)	--	--	---	--	--	---	(ss)
	62	56700	6800	(E)	20.3	358	(E)	20.3	358	(E)	0.1	1.8	(E)	2.4	42.3	(1)	(ss)
	63	--	--	--	74.5(b)	--	(E)	160(b)	--	(E)	0.79(b)	--	(E)	55(b)	--	(E)	(tt)
49	64	34500	4140	(E)	167	4840	(E)	676	19600	(E)	--	--	--	20.7	600	(E)	(uu)
50	65	(D)	(D)	---	(D)	193	(5)	(D)	4880	(5)	(D)	674	(5)	(D)	8960	(5)	(vv)
	65	NA	NA	---	--	--	---	--	--	---	--	--	---	(D)	1391	(39)	(ww)

(n) = Number of data points
-- = Not monitored
AI = Analytical interference
* = Included noncontact cooling water
(E) = Plant estimate
None = No waste water discharged to treatment units
N.D. = Not detectable

(A) = Portions recovered prior to waste water treatment
(B) = Portions incinerated prior to waste water treatment
(C) = Ratios of pollutants to production not calcualted due to batch nature of process and low flow compared to other non-pesticide products
(D) = Ratios of pollutants to production not calculated since waste water is from non-process related washdown only

Table V-2
Page 3 of 4 Pages

NOTES:

PRODUCT CODE:

1 = Toxaphene
2 = 2,4-D
3 = 2,4-DB

4 = MCPA
5 = MCPB

6 = PCNB
7 = Terrazole
8 = DDT
9 = DCPA
10 = Chlorothalonil

11 = Dicofol
12 = Chlorobenzilate
13 = 2,4,5-T
14 = PCP
15 = Endrin
16 = Heptachlor
17 = Diazinon
18 = Dursban
19 = Crufomate
20 = Ronnel
21 = Methyl Parathion
22 = Ethyl Parathion
23 = Apson
24 = Coumaphos
25 = Disulfoton
26 = Fenthion
27 = Azinphos Methyl
28 = Methamidophos
29 = Demeton

30 = Fensulfothion
31 = Oxydemeton
32 = Glyphosate
33 = Stirofos
34 = Dichlorvos
35 = Mevinphos
36 = Naled
37 = Atrazine

SOURCE OF DATA CODE:

(a) Design criteria based on 1970 sampling. Verified in 1975
(b) MRI Toxaphene Report, 2/6/76
(c) Daily time composites, December 13-17, 1976, analyzed by EPA contractor
(d) Daily composite, 7/1/75 thru 2/29/76
(e) Revised plant estimate 3/15/77 including supplementary waste streams not treated by carbon
(f) Daily composites, 8/21/77 thru 10/3/77, analyzed by EPA contractor
(g) MRI Toxaphene Report, 2/6/76
(h) MRI DDT Report, 2/6/76
(i) MRI Toxaphene Report, 2/6/76
(j) Daily composites, 1/5/77 thru 5/16/77, adjusted by total final product ratio of 1.35:1 due to chloral waste water
(k) Daily composite, 2/77
(l) Daily composite, 3/4/77, analyzed by EPA contractor
(m) Daily average 4/74 thru 3/74
(n) Daily flow proportional composite, 5/21/75 thru 6/19/76
(o) Daily average, 8/74 thru 7/75
(p) Daily composite, 6/75
(q) Daily average, 4/72 thru 3/73
(r) Daily composite, 1/74 thru 5/74
(s) Daily flow proportional composite, 5/5/75 thru 6/3/77
(t) Plant estimate, 4/74 thru 3/75
(u) Plant estimate, 1974
(v) Daily composite, 10/1/74
(w) Twelve daily composites during 6/25/75 thru 9/1/75
(x) Daily composite, 3/21/74 thru 5/9/74, analyzed by outside laboratory
(y) Daily composite, 6/74 and 7/74
(z) Daily composite, 1/74
(aa) Two daily composites, 4/74
(bb) Plant estimate, 12/16/74
(cc) Daily flow proportional composite, 5/31/75 thru 6/13/75 Revised data for Disulfoton 3/7/77
(dd) Daily average, 1/74
(ee) Daily average, 2/74
(ff) Daily composites, 2/29/77 thru 3/8/77
(gg) Plant estimate, 1975
(hh) Plant estimate, 10/24/74
(ii) Daily composite, 10/1/74
(jj) Plant estimate, 12/1/74
(kk) Plant estimate, 4/22/76

Table V-2
Page 4 of 4 Pages

38 = Propazine
39 = Simazine
40 = Profluraline

41 = Ametryne

42 = Prometryne

43 = Simetryne

44 = Prometone
45 = Cyanazine
46 = Dinoseb
47 = Metribuzin
48 = Anilazine
49 = Aldicarb
50 = Benfluralin
51 = Ethalfluran
52 = Trifluralin
53 = Isopropalin
54 = Oryzalin
55 = Piperalin
56 = Tebuthiuron
57 = Alachlor
58 = Propachlor
59 = Butachlor
60 = DEET
61 = Bromacil
62 = Diuron
63 = Methomyl
64 = Bentazon
65 = Carbofuran

(ll) Daily composite, 7/9/75 thru 8/13/75
(mm) Plant estimate, 4/5/76
(nn) Daily composites, 1/24/77 thru 1/28/77, analyzed by EPA contractor
(oo) Daily composite, 9/76 thru 3/77, adjusted by total: final production ratio of 1:33:1 to reflect effect of intermediate
(pp) Daily composite, 4/77 thru 5/77, adjusted by total: final production ratio of 1:33:1 to reflect effect of intermediate
(qq) Daily composite, 12/13/76 thru 12/17/76, analyzed by EPA contractor
(rr) Daily composite, 2/77 thru 4/77
(ss) Plant estimate, 5/17/75 and 8/31/77
(tt) Plant estimate, 9/9/77
(uu) Plant estimate, 7/12/77
(vv) Daily composite, 4/77
(ww) Daily composite, 10/76 thru 4/77

Data were available for sixteen halogenated products, including aldrin-toxaphene types, chlorinated aryloxyalkanoic acids and esters, DDT and relatives, halogenated aromatics, and others. Seven direct dischargers of organo-phosphorus pesticides submitted data from in-plant or treatment system influent monitoring. Phosphates and phosphonates, phosphorothioates and phosphorodithioates, and phosphorus- nitrogen compounds are represented among the twenty products with wastewater data available. Of the organo-nitrogen data ten of the twelve plants supplying data are direct dischargers. A total of 29 organo-nitrogen pesticide products are covered, including amides, amide type compounds, carbamates, heterocyclics, nitros, ureas and uracils, s-triazines, and others.

Subcategory 2--Metallo Organic Pesticides Manufacturers

In the manufacturing process for metallo-organic pesticides, the principal sources of waste water are: byproduct stripping, product washing, caustic scrubbing, tank and reactor clean-out and area washdowns. The waste water characteristics associated with these operations are summarized in Table V-3.

A summary of raw waste load characteristics for this subcategory is presented in Table V-4. A total of ten plants submitted data on arsenic, mercury, copper, zinc, tin, iron, and manganese-based pesticides.

A continuing effort is underway to better characterize the waste streams resulting from the manufacture of zinc, iron, manganese, and tin-based products in this subcategory. These four types of compounds are not covered but the Agency intends to regulate the discharge from these manufacturing operations in the future.

Subcategory 3--Formulators and Packagers

Washing and cleaning operations are the principal sources of waste water in formulating and packaging operations. Table V-5 summarizes the wastewater sources for formulating and packaging operations.

Because the primary sources of waste water at formulating plants are associated with cleanup of spills, leaks, area wash-down, and storm water runoff, there is apparently no basis from which to correlate the pollutants generated tc the product made. This has been verified at Plant 101. The analyses available indicate that neither the rate of production nor the type of product formulated has a direct bearing on the quality or quantity of waste water generated.

TABLE V-3

SUMMARY OF POTENTIAL PROCESS--ASSOCIATED WASTEWATER SOURCES FROM METALLO-ORGANIC PESTICIDE PRODUCTION

PROCESSING UNIT	SOURCE	NATURE OF WASTEWATER CONTAMINANTS
Caustic scrubber	Spent caustic solution	High pH, alkalinity, TDS and sulfur content. Low average flow rates. Some dissolved organics.
Intermediate recovery	Wash water, washdown	High TDS, salt content. Arsenic-contaminant brine. Separate organics.
Raw material drum washer	Drum wash water, spills (in recovery)	High arsenic content. No organics. Toxic.
Slurry wash	Product rinse water	High TDS and sulfidic wastes. Low average flow rates. Dissolved and separable organics
Multi-stage counter current washer	Water lost with scrubged salts, clean-out rinse water	High suspended and dissolved solids. Variable heavy metal content. Relatively low flow rates. Very low organic content. Toxic
Air pollution control	Scrubber water	High suspended and dissolved solids. Toxic. Medium flow rates. Low dissolved and separable organics.
By-product stripper	Aqueous fraction	Dissolved organics. High BOD and TOD. Neutral pH.
Tanks and reactors	Clean-out rinse water	Dissolved organics, and suspended and dissolved solids. Intermittent flow rate. Toxic.
All processing areas	Area washdowns	Dissolved and separable organics, and suspended and dissolved solids. Toxic.

TABLE V-4

RAW WASTE LOADS
METALLO-ORGANIC PESTICIDE MANUFACTURERS
SUBCATEGORY 2

PLANT	PRODUCT	FLOW			BOD			COD		
		L/Kkg	gal/1000 Lb	(n)	kg/Kkg	mg/l	(n)	kg/Kkg	mg/l	(n)
19	1	1300	156	(E)	NM	NM	(0)	NM	NM	(0)
20	2	NM	NM	(0)	NM	NM	(0)	NM	NM	(0)
48	2	76310	9150	(E)	54	703	(E)	120	1572	(E)
50	3,4,5,6	None	None	(E)	None	None	(E)	None	None	(E)
53	7,8,9	64270	8000	(E)	23.7	355	(E)	47.5	711	(E)
54	10,11,12	None	None	(E)	None	None	(E)	None	None	(E)
55	1,13	None	None	(E)	None	None	(E)	None	None	(E)
56	1,13	None	None	(E)	None	None	(E)	None	None	(E)
57	14	None	None	(E)	None	None	(E)	None	None	(E)
58	10	None	None	(E)	None	None	(E)	None	None	(E)

(E) = Plant Estimate
NM = Not Monitored

TABLE V-4
Continued
Page 2 of 3 Pages

PLANT	PRODUCT	TSS			METAL			SOURCE OF DATA
		kg/Kkg	mg/l	(n)	kg/Kkg	mg/l	(n)	
19	1	NM	NM	(0)	0.0817	0.359	(34)	(a)
20	2	NM	NM	(0)	NM	NM	(0)	(b)
48	2	137	1718	(E)	37	481	(E)	(c)
50	3,4,5,6	None	None	(E)	None	None	(E)	(d)
53	7,8,9	253	3800	(E)	4	60	(E)	(e)
54	10,11,12	None	None	(E)	None	None	(E)	(f)
55	1,13	None	None	(E)	None	None	(E)	(g)
56	1,13	None	None	(E)	None	None	(E)	(h)
57	14	None	None	(E)	None	None	(E)	(i)
58	10	None	None	(E)	None	None	(E)	(j)

(E) = Plant Estimate
NM = Not Monitored

TABLE V-4
Continued
Page 3 of 3 Pages

PRODUCT CODE:

1 = MSMA
2 = Maneb
3 = Zineb
4 = Ziram
5 = Polyram
6 = Ferbam
7 = Tricyclohexyltin Hydroxide
8 = Triphenyltin Hydroxide
9 = Tributyltin Oxide
10 = PMA
11 = Copper Napthenate
12 = CMP
13 = DSMA
14 = Oxine Copper

SOURCE OF DATA CODE:

(a) Daily samples, 1/5/77. Flow estimate, 8/29/77, includes stormwater.
(b) Plant visit, 2/15/77.
(c) Plant estimate, 5/21/75.
(d) Plant visit, 1/6/77.
(e) Plant estimate, 5/23/75.
(f) Plant estimate, 5/7/76.
(g) Plant estimate, 5/14/76.
(h) Plant estimate, 5/14/76.
(i) Plant estimate, 5/13/76.
(j) Plant estimate, 4/13/76.

TABLE V-5

SUMMARY OF POTENTIAL PROCESS--ASSOCIATED WASTE WATER SOURCES FROM PESTICIDE FORMULATORS AND PACKAGERS

PROCESSING UNIT	SOURCE	NATURE OF WASTE WATER CONTAMINANTS
Mix tank	Condensate from equipment steam cleaning	Dissolved organics, and suspended and dissolved solids. Non-continuous flow rate, and relatively low flow. pH variable
Air pollution control equipment	Scrubber water	High suspended and dissolved solids, and dissolved organics. Relatively low flow rate.
Formulation lines and filling equipment	Wash water and steam condensate from clean out	Dissolved organics, and suspended and dissolved solids. A major potential source of waste water.
All product formulation and blending areas	Area washdown and clean-up water, spills, leaks	Dissolved organics, suspended and dissolved solids and intermittent low flow.
Warehouse, technical active ingredient storage	Spills, leaks, run-off	Dissolved organics, suspended and dissolved solids and intermittent low flow.

In one survey 75 plants were contacted which formulate wet, dry, or solvent based pesticides. No plant which solely formulates or packages was found that discharged waste water to a navigable waterway. One major formulator operating 38 plants of varying size and process (wet, dry, and solvent) achieved no discharge over a thirteen state area through hauling and evaporation. Other Agency surveys revealed the same results. Wastewater volume generated by these plants ranged from zero to 5800 gal/day. A majority of plants surveyed reported from zero to 1000 gal/day generated.

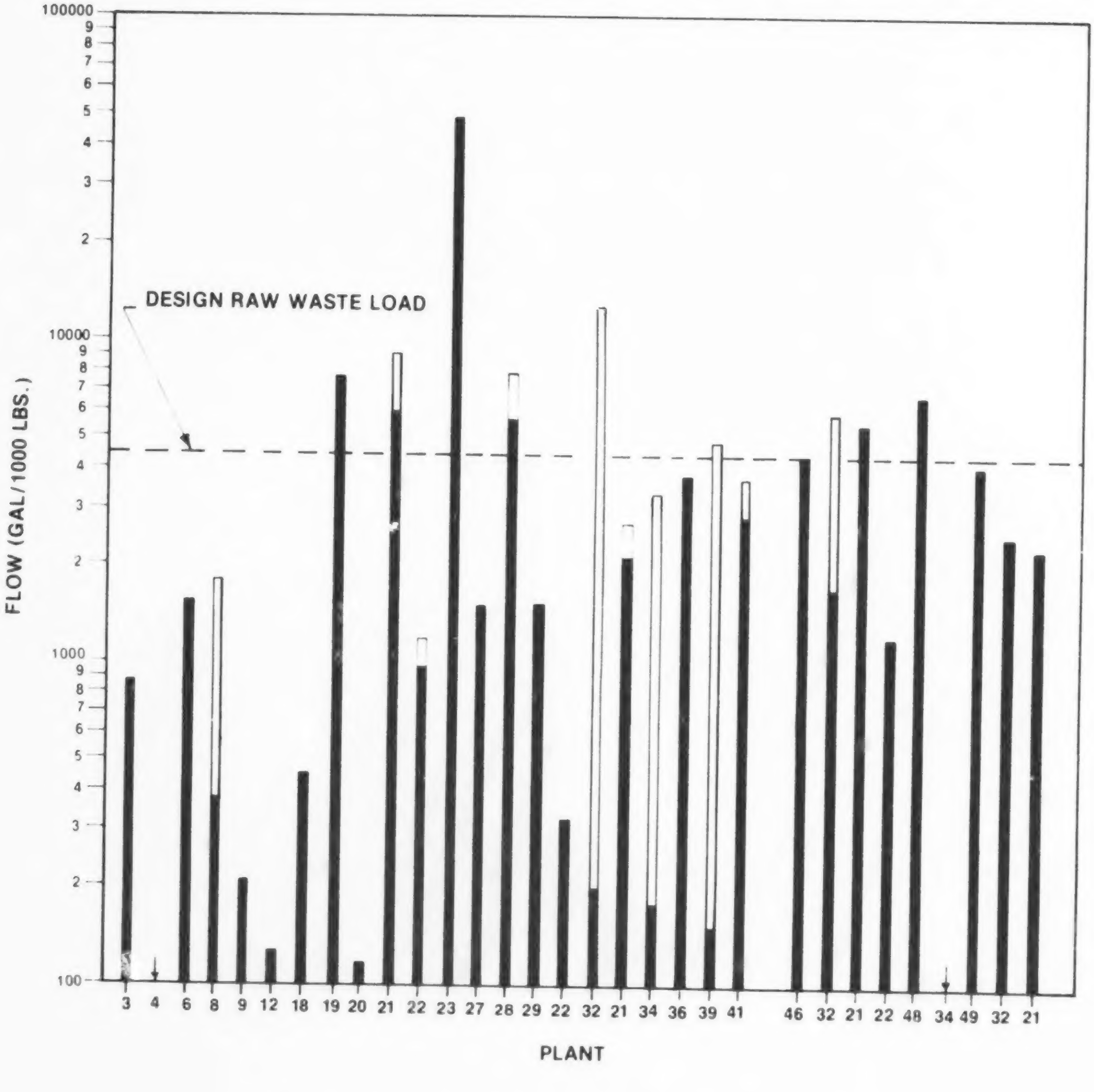
Raw Waste Load Design Criteria

The raw waste load characteristics previously presented form the basis for the design and cost of the treatment technologies to be developed in Sections VII and VIII. The purpose for developing design criteria is solely to allow for subsequent cost calculations, and is not related to the development of effluent limitations as documented in Section IX.

Figures V-1 through V-6 show the relative raw waste load values (kg/kkg) for halogenated, phosphorus, and nitrogen pesticide producing plants. These figures have been derived from data presented in previous tables in Section V. The range of values observed demonstrates the problems of obtaining comparable data when different products, processes, and methods of disposal are utilized by each plant. There is no correlation between these data to justify subcategories.

The design raw waste load selected has been indicated graphically in each figure. By selecting upper level values for each parameter, a generous estimate of the raw waste load is made, as it is highly unlikely that any one plant would exceed these values in every case. Solid bars indicate an average value for all products manufactured at a plant. Maximum values for different products or different estimates for the same products are represented by empty bars.

A range of production values encountered in the industry has been utilized in conjunction with the raw waste loads. Flow and concentration levels have been calculated. The design criteria to be utilized with the treatment units specified in Section VII are presented in Table V-6.



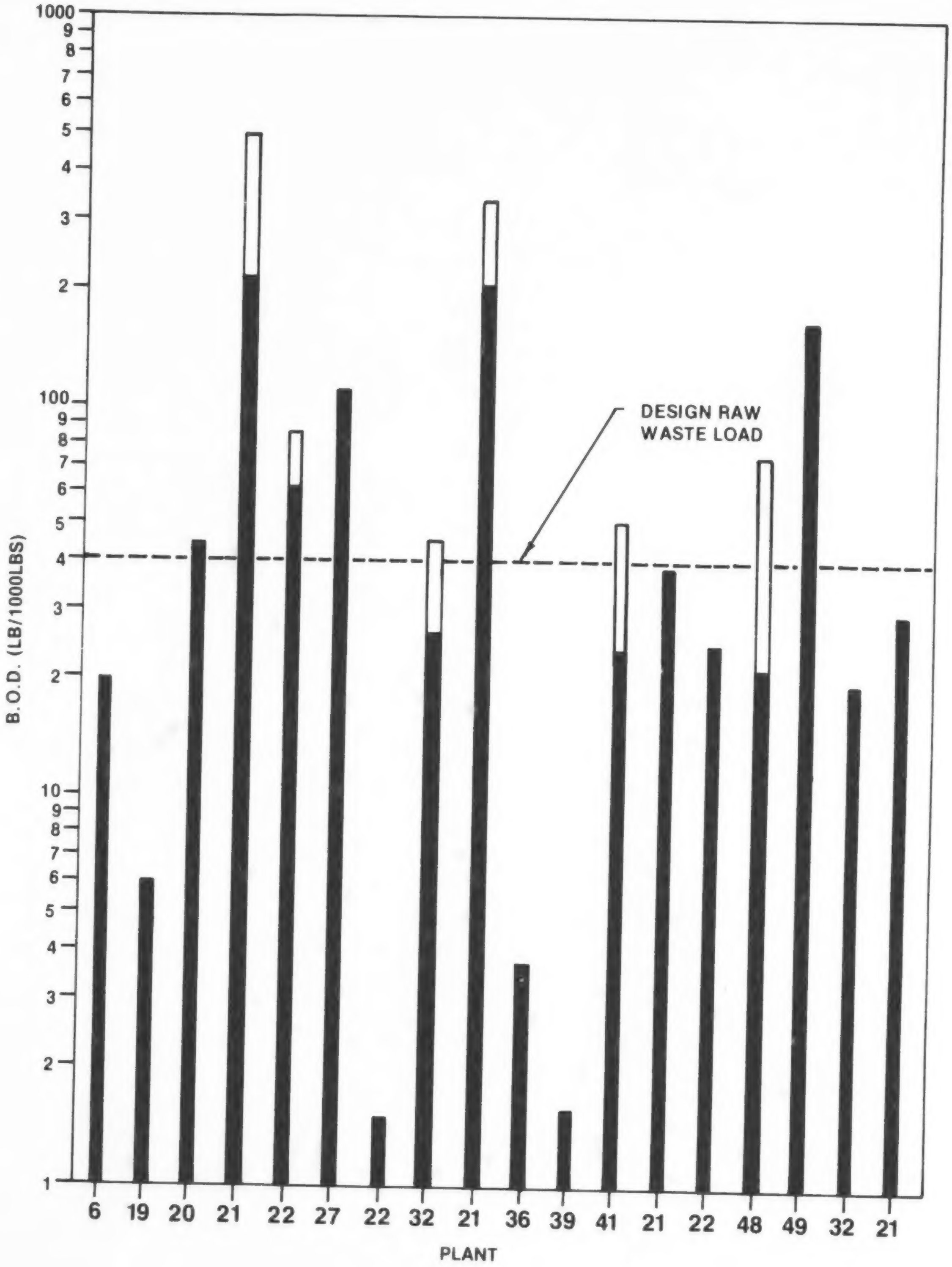
FLOW RAW WASTE LOAD CHARACTERISTICS
PESTICIDES MANUFACTURERS

▬ AVERAGE FOR PARAMETER

▬▭ MINIMUM AND MAXIMUM FOR PARAMETER

↓ INDICATES LEVEL BELOW 100 GAL/1000 LBS.

FIGURE V-1

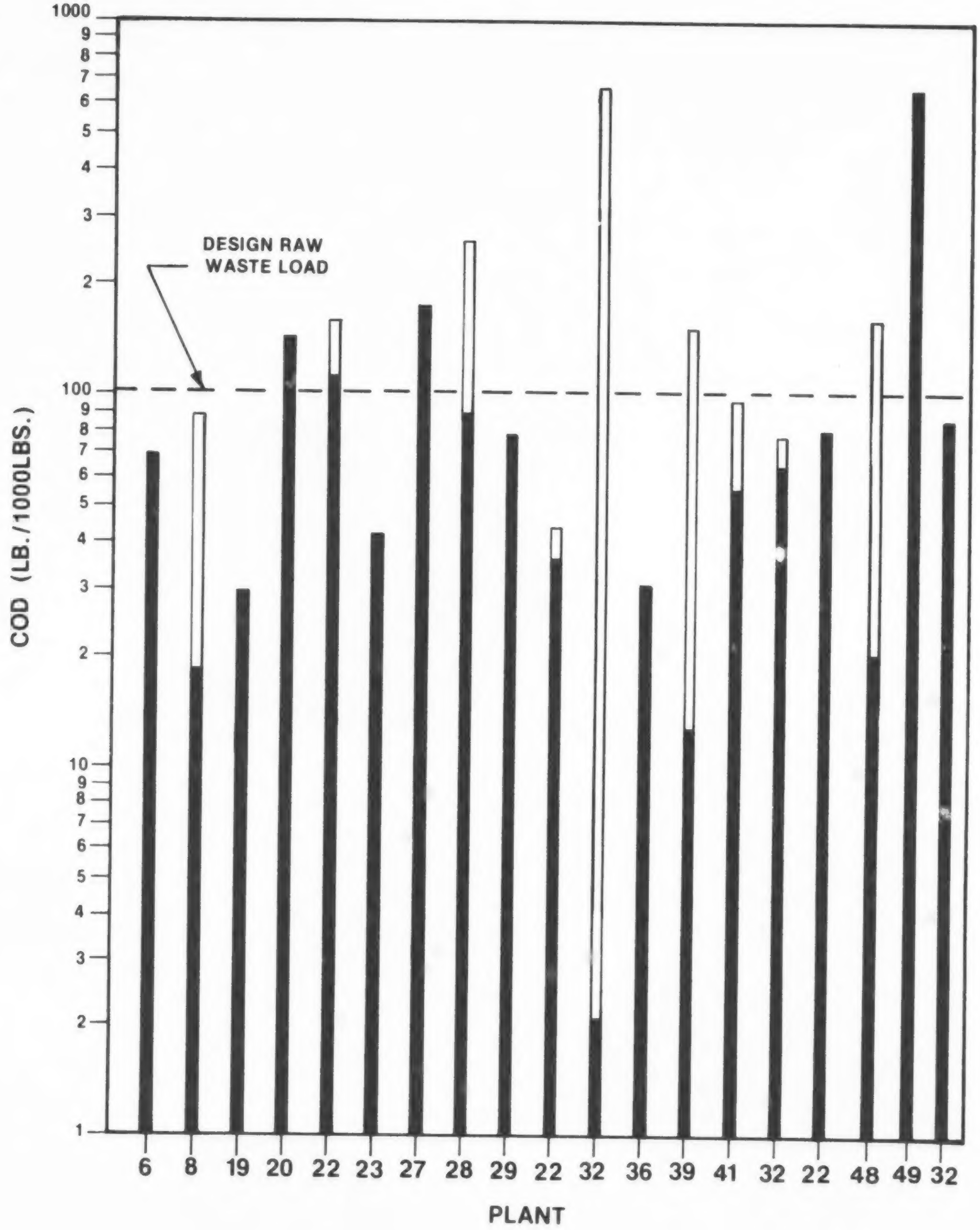


BOD RAW WASTE LOAD CHARACTERISTICS
PESTICIDES MANUFACTURERS

▬ AVERAGE FOR PARAMETER

▬▭ MINIMUM AND MAXIMUM FOR PARAMETER

FIGURE V-2

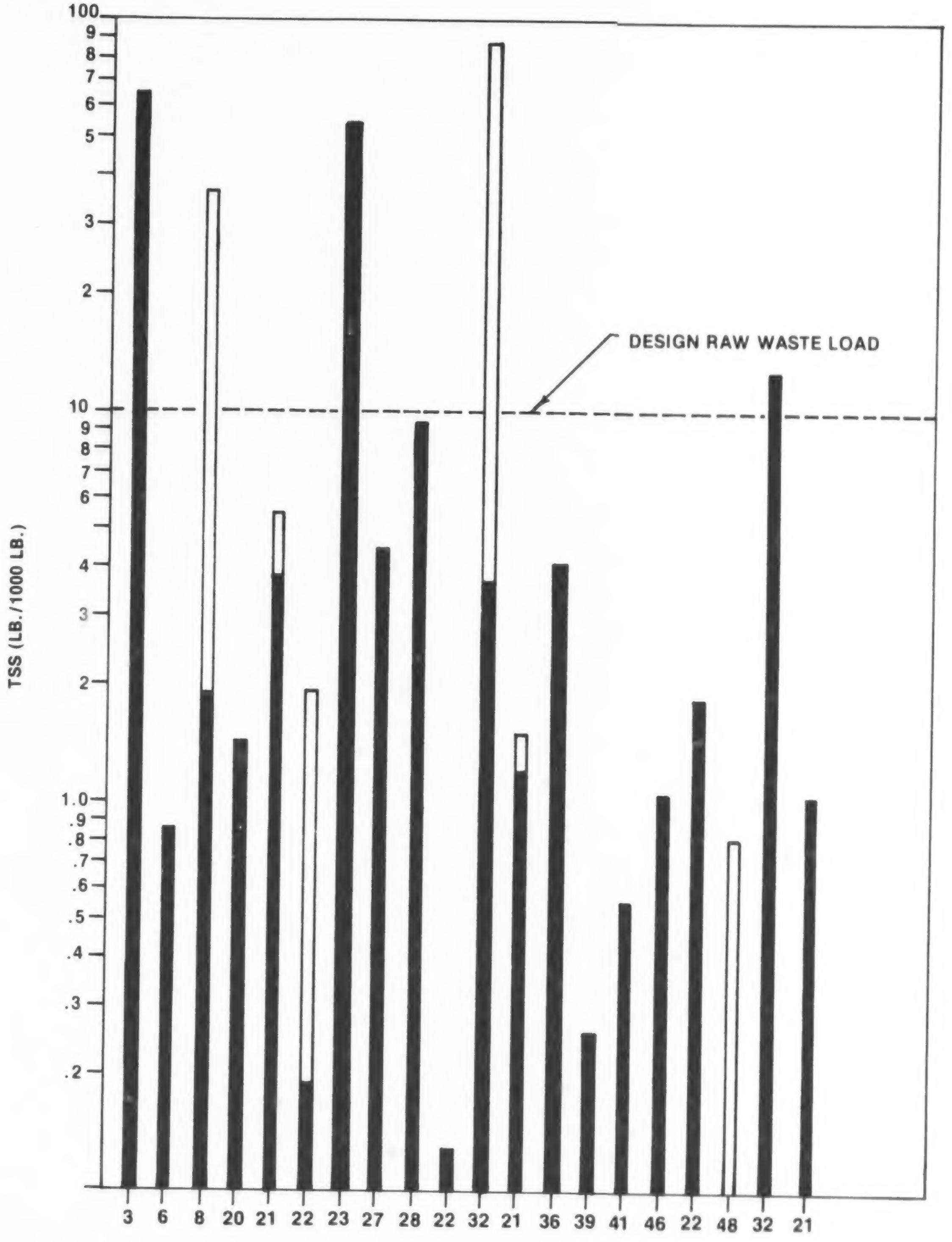


COD RAW WASTE LOAD CHARACTERISTICS
PESTICIDES MANUFACTURERS

■ AVERAGE FOR PARAMETER

■□ MINIMUM AND MAXIMUM FOR PARAMETER

FIGURE V-3

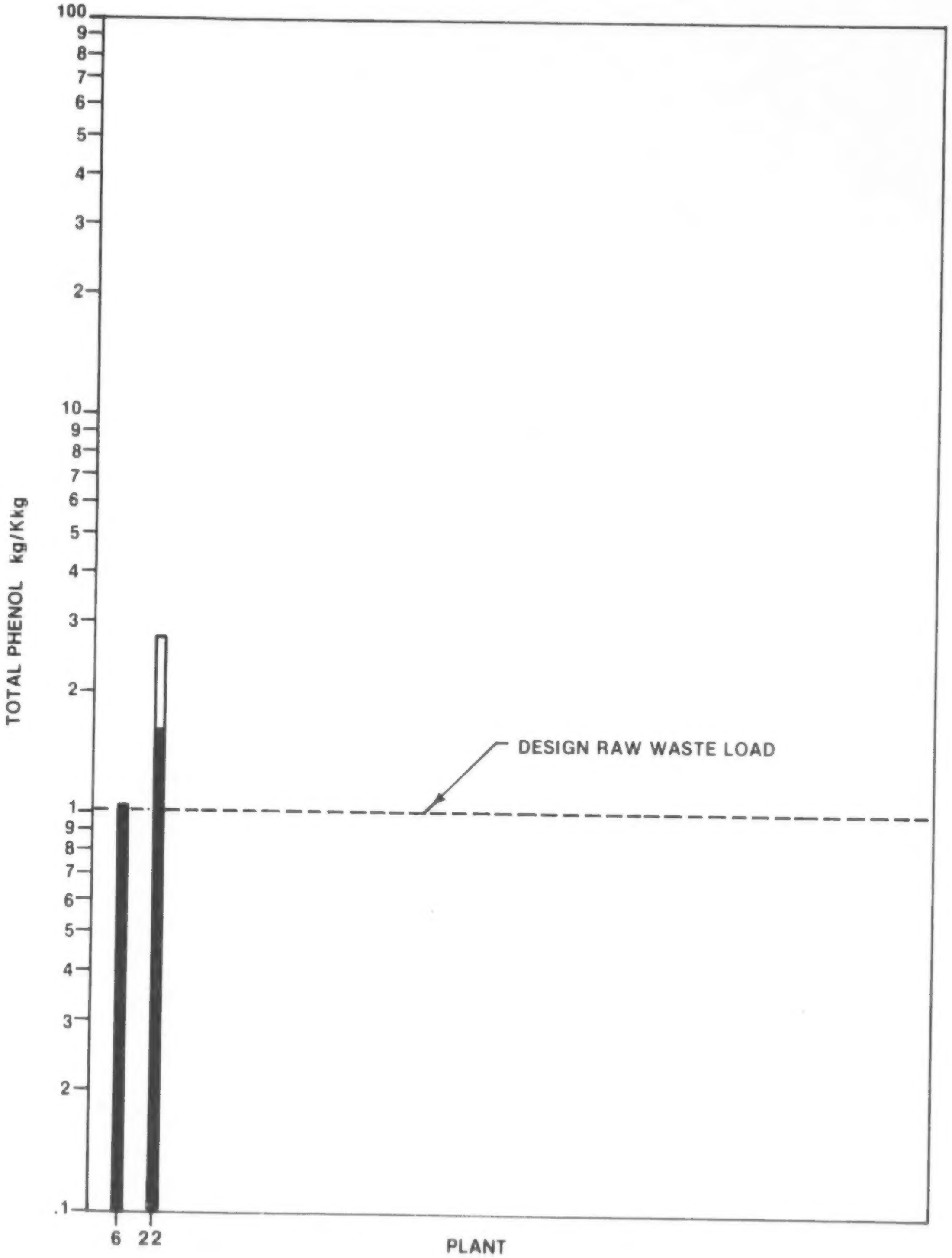


TSS RAW WASTE LOAD CHARACTERISTICS
PESTICIDES MANUFACTURERS

■ AVERAGE FOR PARAMETER

■□ MINIMUM AND MAXIMUM FOR PARAMETER

FIGURE V-4

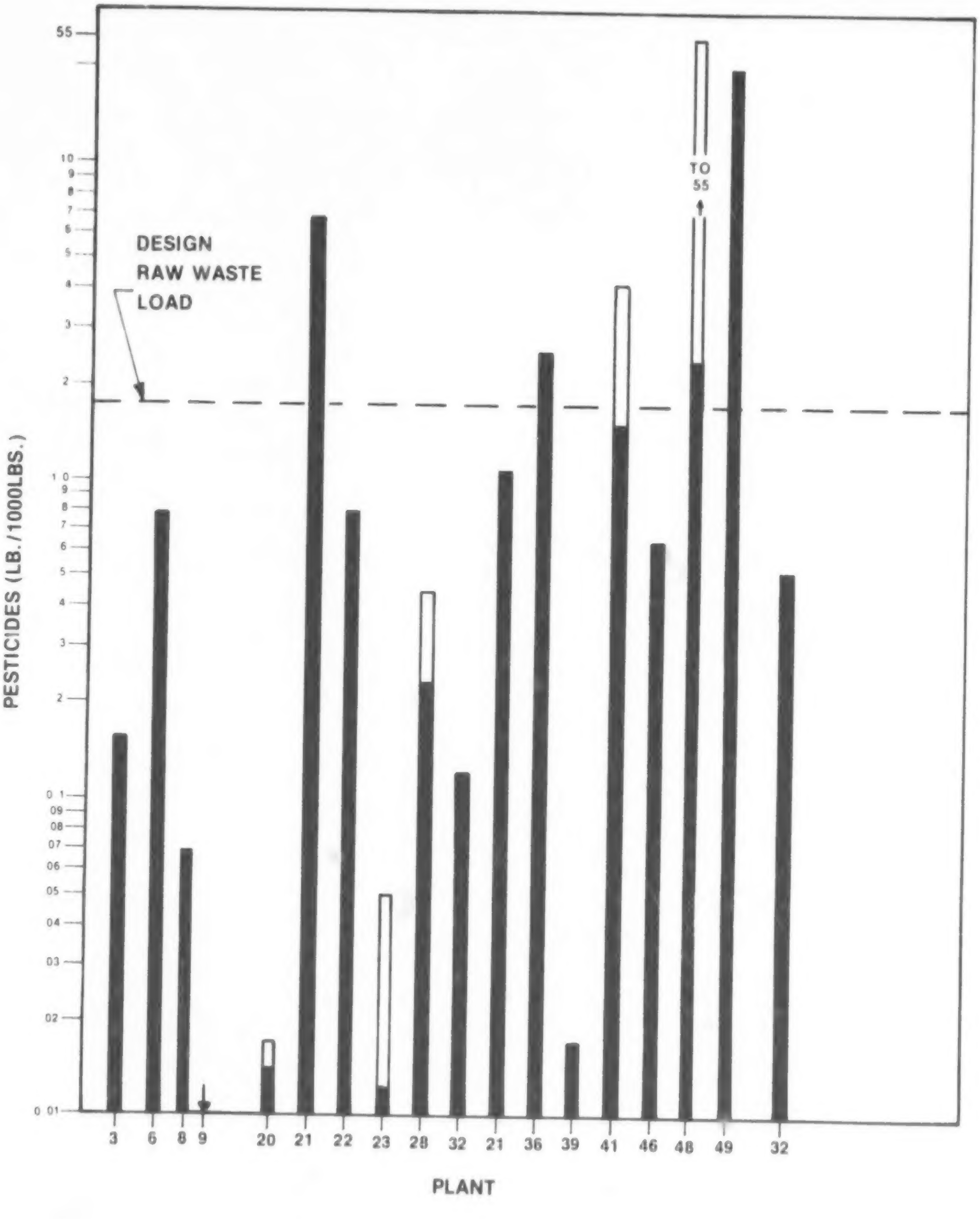


TOTAL PHENOL RAW WASTE LOAD CHARACTERISTICS
PESTICIDES MANUFACTURERS

■ AVERAGE FOR PARAMETER

■□ MINIMUM AND MAXIMUM FOR PARAMETER

FIGURE V-5



PESTICIDES RAW WASTE LOAD CHARACTERISTICS
PESTICIDES MANUFACTURERS

▬ AVERAGE FOR PARAMETER

▬☐ MINIMUM AND MAXIMUM FOR PARAMETER

↓ INDICATES LEVEL BELOW 0.01 LB./1000 LBS

FIGURE V-6

TABLE V-6

DESIGN CRITERIA
COST TREATMENT TECHNOLOGY
SUBCATEGORY 1

Design Loads:	Flow = 4500 gal/1000 lb BOD = 40 lb/1000 lb TSS = 10 lb/1000 lb Pesticides = 1.75 lb/1000 lb
Design Flows:	0.9 MGD 0.2 MGD 0.045 MGD
Design Concentrations:	BOD = 1070 mg/l TSS = 266 mg/l Pesticides = 45.5 mg/l

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

The pollutants which are of primary significance for the pesticide chemicals industry are as follows:

Organic Pollutants	Pesticide Chemicals
Suspended Solids	Metals
pH	

The adverse effects of primary concern with respect to pesticide chemicals waste waters are as follows:

a. the oxygen demanding capacity of organic materials which will depress dissolved oxygen (DO) levels of receiving waters;

b. the aesthetic and physically inhibiting effects of excessive levels of suspended solids;

c. the capacity to alter receiving water pH;

d. the potential contribution to eutrophic conditions in receiving waters;

e. the toxic nature of pesticides, metals, phenol, and cyanide to aquatic organisms present in receiving waters; and

f. the danger of long-term buildup in aquatic organisms and man of persistent pesticides which may have human health implications.

The pollutants of primary significance are not all likely to be present at high concentrations in every pesticide plant's waste water. Organic wastes, suspended solids, pH, and nutrients are potential pollutants for any of the subcategories. Pesticide active ingredients are specific to the product manufactured or used in formulating and packaging. Metals may be present in waste waters at those facilities where metallo-organic pesticide chemicals are produced or where metals are employed in the production process.

Preceding page blank

Other pollutants of significance in the pesticide chemicals industry include the following:

- Ammonia
- Nutrients
- Settleable solids
- Dissolved solids
- Alkalinity
- Oil and Grease
- Cyanide
- Phenol
- Acidity
- Chloride
- Sulfide

These pollutants may be of concern in a particular location, but they are generally of less importance than the pollutants of primary significance. They can usually be assessed indirectly by measurement of pollutants of primary significance.

The following discussion indicates the basis for selection of parameters to be regulated. Parameters are discussed in terms of their relevance to the treatment recommended and their validity as analytical measurements and indicators of environmental impact.

Pollutants of Primary Significance

Organic Pollutants

Organic pollutants which are amenable to biological and chemical decomposition in receiving waters exert an oxygen demand on these waters during the process of decomposition. Oxygen demanding wastes consume dissolved oxygen (DO). DO is essential for living organisms and is essential to sustain species reproduction, vigor, and the development of populations. Organisms undergo stress at reduced DO concentrations that make them less competitive and less capable of sustaining their species within the aquatic environment. For example, reduced DO concentrations have been shown to interfere with fish populations through delayed hatching of eggs, reduced size and vigor of embryos, increased deformities in the young, interference with food digestion, acceleration of blood clotting, decreased tolerance to certain toxicants, reduced food utilization efficiency and growth rate, and reduced maximum sustained swimming speed. Fish food organisms are likewise affected adversely in conditions of depressed DO. Since all aerobic aquatic organisms need a certain amount of oxygen, the occurrence of a total lack of dissolved oxygen due to a high oxygen demand of wastes can kill all aerobic inhabitants of the effected area.

The three methods commonly used to measure the organic content of waste waters are Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Organic Carbon (TOC). Each of these methods have certain advantages and disadvantages when applied to industrial waste waters.

The BOD test is essentially a bioassay procedure involving the measurement of oxygen consumed by living organisms while utilizing the organic matter present in a waste water under conditions as similar as possible to those that occur in nature. Historically, the BOD test has been used to evaluate the performance of biological waste water treatment facilities and to establish effluent limitation values. It is important to note that most state, local and regional authorities have established water quality regulations utilizing BOD as the major parameter for determination of oxygen demand on a water body. When properly performed, the BOD test measures the actual amount of oxygen consumed by microorganisms in metabolizing the organic matter present in the waste water. Some limitations to the use of the BOD test are discussed below (WPCF, 1975, ref. 456).

The standard BOD test takes five days before the results are available. Although BOD is a good measure of long-term treatment performance, other parameters which can be determined more readily are more suitable as treatment system controlling parameters.

Because the BOD test is sensitive to toxic materials, their presence in a particular waste water may result in incorrect BOD values. Toxicity is generally indicated by higher BOD values measured on repeated dilutions of the samples. This situation should be remedied by conducting further dilutions, i.e., serially diluting the sample until the BOD value reaches a plateau indicating that the material is at a concentration which no longer inhibits biological oxidation.

The chemical oxygen demand (COD) determination provides a measure of the oxygen equivalent of that portion of the organic matter in a sample that is susceptible to chemical oxidation. The carbonaceous portion of nitrogenous compounds can be determined by the COD test, and there is questionable reduction of the dichromate by ammonia. With certain wastes containing toxic substances, this test or a total organic carbon (TOC) determination may be the best method for determination of the organic load. Since the test utilizes chemical oxidation rather than a biological process, the result is not always exactly related to the BOD of a waste water. The test result should be considered as an independent measurement of organic matter in the sample, rather than as a substitute for the BOD test (USEPA, 625/6-74-003, 1974, ref. 3261).

The ratio of COD to BOD is an empirical relationship which varies in each individual waste streams and accordingly has not been utilized in development of these regulations.

The TOC analysis offers a third option for measurement of organic pollutants in waste waters. The method measures the total organic carbon content of the waste water by a combustion method. The results may be used to assess the potential oxygen-demanding load exterted by the carbonaecous portion of a waste on a receiving stream. There is generally no correlation among TOC and BOD or COD for different waste streams. A correlation must be determined for each waste water by comparison of analytical results. TOC analysis is rapid and generally accurate and reproducable. However, it requires analytical instrumentation which may be relatively expensive if not utilized fully. There presently does not exist a sufficient data base from which to regulate TOC in this industry.

The fourth option for measurement of organic pollutants in waste waters is total oxygen demand (TOD). Like TOC, TOD measures the parameter by a combustion method. The TOD method is based on the quantitive measurement of the amount of oxygen used to burn the impurities (pollutants) in a liquid sample. TOD, like TOC, requires expensive equipment to run and is not cost effective unless utilized fully. The correlations of BOD and COD with TOD are the same as with TOC described above.

It is therefore concluded that effluent limitations and guidelines for organic pollutants in terms of both BOD and COD are necessary for subcategory 1 of the pesticide chemicals manufacturing point source category. In certain circumstances TOD may be substituted for COD and TOC for BOD. However, an adequate correlation between these parameters should be established.

Total Suspended Solids (TSS)

Suspended solids are usually composed of organic and inorganic fractions. These fractions, in turn, may be made up of readily settleable, slowly settleable, or non-settleable materials. The biodegradable organic fraction will exert an oxygen demand on a receiving water and is reflected in the analyses for organics discussed above.

Suspended solids in water interfere with many industrial processes, causing foaming in boilers and incrustations on equipment exposed to such water, especially as the temperature rises. They are undesirable in process water used in the manufacture of steel, in the textile industry, in launderies, in dyeing and in cooling systems.

When solids settle to form sludge deposits on a stream or lake bed, they are often damaging to the life in water. Sludge deposits may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat. Organic materials also serve as a food source for sludgeworms and associated organisms.

Solids in suspension are aesthetically displeasing. Suspended solids may kill fish and shellfish by causing abrasive injuries and by clogging the gills and respiratory passages. Indirectly, suspended solids are inimical to aquatic life because they screen out light and promote and maintain the development of noxious conditions through oxygen depletion. This results in the killing of fish and fish food organisms. Suspended solids also reduce the recreational value of the water.

The control of suspended solids from bioloigcal treatment systems is especially critical. Not only does the biomass exert an oxygen demand on receiving waters, but for the pesticide chemicals industry there is evidence that substantial quantities of toxic residues are absorbed on or in the floc which, if carried over, will potentially cause a toxic effect in the receiving waters.

Therefore, it is concluded that TSS is an essential pollutant parameter requiring control for subcategory 1 of the pesticide chemicals industry.

pH

The pH is related to the acidity or alkalinity of a waste water stream. Although it is not a linear or direct measure of either, it may properly be used as a surrogate to control both excess acidity and excess alkalinity in water. The term pH is used to describe the hydrogen ion-hydroxyl ion balance in water. pH is the negative logarithim of the hydrogen ion concentration. A pH of 7 generally indicates neutrality or a balance between free hydrogen and free hydroxyl ions. A pH above 7 indicates that a solution is alkaline, while a pH below 7 indicates that the solution is acid.

Knowledge of the pH of water or waste water is useful in determining necessary measures for corrosion control, pollution control, and disinfection. Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures. Also, corrosion can add constituents such as iron, copper, zinc, cadmium, and lead to drinking water. Low pH waters not only tend to dissolve metals from structures and fixtures but also tend to dissolve or leach metals from sludges and bottom sediments. The hydrogen ion concentration can affect the "taste" of water and, at a low pH, water tastes "sour".

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in the pH. For example, metalocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units. Similarly, the toxicity of ammonia is a function of pH. The bactericidal effect of chlorine is diminished as the pH increases in most cases. In addition, it is economically advantageous to keep the pH close to 7, (US EPA, 440/9-76-023, 9/76, ref. 407).

It is therefore concluded that pH is a significant parameter requiring control in the pesticide chemicals industry.

Pesticide Chemicals

Pesticides are, by their very nature and use, toxic to certain living organisms. They can be a hazard to aquatic life, terrestrial life, and man when allowed to enter natural waters in sufficient amounts. Pesticides may affect the aquatic environment and water quality in several ways. A pesticide with a slow rate of degradation will persist in the environment, suppressing or destroying some organism populations while allowing others to gain supremacy. An imbalance in the ecosystem results. Other pesticides will degrade rapidly, some to products that are more toxic than the parent compound, some to relatively harmless products and some to products for which toxicity data are lacking. Many pesticides have a high potential for bioaccumulation and biomagnification in the aquatic food chain, thereby posing a serious threat to a large number of ecologically important organisms, including man (FWPCA, 1968, ref. 93).

The chlorinated hydrocarbons are among the most widely used groups of synthetic organic pesticides. They are stable in the environment, toxic to wildlife and nontarget organisms, and have adverse physiological effects on humans. These pesticides readily accumulate in aquatic organisms and in man. They are stored in fatty tissue and are not rapidly metabolized. Humans may accumulate chlorinated hydrocarbon residues by direct ingestion of contaminated water or by consumption of contaminated organisms. Regardless of how chlorinated hydrocarbons enter organisms, they induce poisoning having similar symptoms that differ in severity. The severity is related to the extent and concentration of the compound in the nervous system, primarily the brain. Deleterious effects on human health are also suspected to result from long-term, low-level exposure to this class of compounds (FWPCA, 1968, ref. 93).

The organo-phosphorus pesticide chemicals typically hydrolyze or break down into less toxic products more rapidly than the halogenated compounds. Generally they persist for less than a year. Some last for only a few days in the environment. They exhibit a wide range of toxicity, both more and less damaging to aquatic fauna than the chlorinated hydrocarbons. Some exhibit a high mammalian toxicity. Accumulation of some of these pesticides results in a dysfunction of the cholinesterase of the nervous system when ingested in small quantities over a long period of time (FWPCA, 1968, ref. 43).

The organo-nitrogen pesticide chemicals are also generally less persistent in the environment than the chlorinated hydrocarbons. They exhibit a wide range of toxicity. The carbamates are particularly toxic to mammals. They appear to act on the nervous system in the same manner as the organo-phosphorus pesticides.

Metallo-organic pesticide chemicals include compounds containing arsenicals, mercury. The toxicity of these compounds is highly variable.

Arsenic is notorious for its toxicity to humans. Ingestion of 100 mg usually results in severe poisoning and 130 mg has proved fatal. The organo-arsenic compounds such as cacodylic acid are even more toxic to humans and to aquatic organisms. Arsenic accumulates in the human body so that small doses may become fatal in time. Mercuro-organic compounds are highly toxic and exhibit bioaccumulation and biomagnification. They may be converted by benthic organisms to the highly-toxic methyl mercury. They have been shown to reduce photosynthesis at 0.1 ug/l in lake waters (USEPA, 440/9-76-023, 9/76, ref. 407).

Analyses of pesticides in waste water are generally accomplished by either colorimetric or gas chromatographic methods with electron capture detector. For some pesticide chemicals, such as toxaphene, gas chromatograph - mass spectrometry analysis (GC/MS) may be required. The colorimetric methods available for certain of the pesticides are simple and straight forward. Gas chromatographic methods are more involved and require the expertise of trained analytical chemists and the use of relatively costly instrumentation. GC/MS is even more costly and difficult to run. Procedures for analysis of pesticides in waste waters can be obtained from the Environmental Monitoring and Support Laboratory in Cincinnati, Ohio.

Although the pesticide chemicals considered in this document are organic compounds, they are not adequately measured by BOD, COD, or TOC. They are often toxic to organisms used in the BOD analysis. The determination of small quantities of pesticides, is marked by the presence of large quantities of materials measured by COD and TOC. Therefore, pesticides should be specifically measured.

Metals

Metals may enter waste waters of the pesticide chemicals industry when they are used as a principal constituent of metallo-organic pesticides, and when used in intermediate production steps or as catalysts. Metals can be a hazard to both aquatic organisms and to man. The principal metals of concern with respect to the pesticide chemicals industry are the following:

- Arsenic
- Cadmium
- Chromium
- Copper
- Lead
- Manganese
- Mercury
- Nickel
- Tin
- Zinc

Arsenic is a cumulative poison with long-term chronic effects on both aquatic organisms and on mammalian species, and a succession of small doses may add up to a final lethal dose. It is moderately toxic to plants and highly toxic to animals, especially as arsenic hydride. Surface water criteria for public water supplies have set a permissible level of arsenic in those waters at 0.05 mg/l (US EPA, 440/9-76-023, 9/76, ref. 407).

Cadmium in drinking water supplies is extremely hazardous to humans. Cadmium accumulates in the liver, kidney, pancreas, and thyroid of humans and other animals. A severe bone and kidney syndrome in Japan has been associated with the ingestion of as little as 600 ug/day of cadmium. Cadmium may also form organic compounds which lead to mutagenic or teratogenic effects. It is known to have acute and chronic effects on aquatic organisms (US EPA, 440/9-76-023, 9/76, ref. 407).

Cadmium acts synergistically with other metals. Copper and zinc substantially increase its toxicity. Cadmium is concentrated in marine organisms, particularly mollusks, which accumulate cadmium in calcareous tissues and in the viscera. A concentration factor of 1,000 for cadmium in fish muscle has been reported, as have concentration factors of 3,000 in marine plants, and up to 29,600 in certain marine animals. The eggs and larvae of fish are apparently more sensitive than adult fish to poisoning by cadmium, and crustaceans appear to be more senitive than fish eggs and larvae (US EPA, 440-9/76-023, 9/76, ref. 407). The maximum amount of cadmium allowable in drinking water supplies is 0.01 mg/l in the United States (US EPA, 440/9-76-023, 9/76, ref. 407).

Copper salts occur in natural surface waters only in trace amounts, up to about 0.05 mg/l; consequently, their presence generally is the result of pollution. This is attributable to the corrosive action of the water on copper and brass tubing, to industrial effluents, and frequently to the use of copper compounds for the control of undersirable plankton organisms (WPCF, 1975, ref. 456).

Copper is not considered to be a cumulative systemic poison for humans, but it can cause symptoms of gastroenteritis, with nausea and intestinal irritations, at relatively low dosages. Excess copper ingestion is known to cause chronic zinc deficiency. Copper also affects tastes in waters. Threshold concentrations for taste have been generally reported in the range of 1.0 to 2.0 mg/l of copper, while 5 to 7.5 makes the water completely unpalatable, (WPCF, 1975, ref. 456).

The toxicity of copper to aquatic organisms varies significantly, not only with the species but also with the physical and chemical characteristics of the water, including temperature, hardness, turbidity, and carbon dioxide content. In hard water, the toxicity of copper salts is reduced by the precipitation of copper carbonate or other insoluable compounds. The sulfates of copper and zinc, and of copper and calcium, are synergistic in their toxic effect on fish (US EPA, 440/9-76-023, 9/76, ref. 407).

Copper concentrations less than 1 mg/l have been reported to be toxic (particularly in soft water) to many kinds of fish, crustaceans, mollusks, insects, phytoplantkon, and zooplankton. Concentrations of 0.1 mg/l copper, are detrimental to some oysters. Oysters cultured in sea water containing 0.13 to 0.5 mg/l of copper retained the metal in their bodies and became unfit as food (US EPA, 440/9-76-023, 9/76, ref. 407).

Chromium, in its various valence states (hexavalent and trivalent), is hazardous to man. Large doses of chromates have corrosive effects on the intestinal tract and can cause inflammation of the kidneys. Levels of chromate ions that have no effect on man appear to be so low as to prohibit determination to date (US EPA, 440/9-76-023, 9/76, ref. 407).

The toxicity of chromium salts to aquatic life varies widely with the species, temperature, pH, valence of the chromium, and synergistic or antagonistic tolerance of chromium salts; however, fish food organisms and other lower forms of aquatic life are extremely sensitive. Chromium also inhibits the growth of algae (US EPA, 440/9-76-023, 9/76, ref. 407).

Lead is foreign to the human body, and tends to accumulate in bones. A universally safe level of lead has not been established. Lead poisoning usually results from the cumulative toxic effects of lead after continuous exposure over a long period of time, rather than from occasional small doses. Lead is not considered essential to the nutrition of animals or human beings. The maximum allowable limit for lead in the USPHS Drinking Water Standards is 0.05 mg/l (US EPA, 440/9-76-023, 9/76, ref. 407).

It is not unusual for cattle to be poisoned by lead in their water. The lead need not be in solution to be harmful, but may be in suspension, as for example oxycarbonate. Chronic lead poisoning among animals has been caused by 0.10 mg/l of lead in soft water. Most authorities agree that 0.5 mg/l of lead is the maximum safe limit for lead in a potable supply for animals. The toxic concentration of lead for aerobic bacteria is reported to be 1.0 mg/l, and for flagellates and infusoria, 0.5 mg/l. The bacterial decomposition of organic matter is inhibited by 0.1 to 0.5 mg/l of lead.

Studies indicate that in water containing lead salts, a film of coagulated mucus forms first over the gills and then over the whole body of the fish, probably as a result of a reaction between lead and an organic constituent of mucus. The death of the fish is caused by suffocation due to this obstructive layer (McKee, 1971). Lead is relatively more toxic in soft water than hard water. Concentrations of lead as low as 0.1 mg/l have been reported toxic or lethal to fish. Other studies have shown that the toxicity of lead toward rainbow trout increases with a reduction of the dissolved-oxygen concentration of the water (US EPA, 440/9-76-023, 9/76, ref. 401).

Manganese is an essential nutrient in plant and animal life. Deficiencies of manganese in animals produce lack of growth, bone abnormalities, and symptoms of central nervous system disturbance. However, manganese is toxic to humans in extremely high concentrations. It appears somewhat antagonistic to the toxic action of nickel on fish.

Manganese may interfere with water usage since it stains materials, especially when the pH is raised as in laundering, scouring, or other washing operations. These stains, if not masked by iron, may be dirty brown, gray or black in color, and usually occur in spots and streaks. Waters containing manganous bicarbonate cannot be used in the textile industries, in dyeing, tanning, laundering, or in many other industrial uses. In the pulp and paper industry, waters containing above 0.05 mg/l manganese cannot be tolerated except for low-grade products. Very small amounts of manganese 0.2 to 0.3 mg/l, may form heavy encrustations in piping, while even smaller amounts may form noticable black deposits (US EPA, 440/9-76-023, 9/76, ref. 407).

Mercuric salts are highly toxic to humans and can be readily absorbed through the gastointestinal tracts. Fatal doses can vary from 3 to 30 grams. The drinking water criteria for mercury is 2 ug/l.

Mercuric salts are also extremely toxic to fish and other aquatic life. Mercuric chloride is more lethal than copper, hexavalent chromium, zinc, nickel, and lead to fish and aquatic life. In the food cycle, algae containing mercury in an amount up to 100 times the concentration of the surrounding sea water are eaten by fish which further concentrate the mercury, and predators that eat the fish in turn concentrate the mercury even further. The criterion for mercury in freshwater is 0.05 ug/l for protection of aquatic life. For marine life, the criterion is 0.1 ug/l (US EPA, 440/9-76-023, 9/76, ref. 407).

Nickel and tin do not appear to pose as serious threats to receiving waters as the other heavy metals. Nickel is toxic to aquatic life and to plants. Little is known about tin as a pollutant problem. A criteria of 100 ug/l has been recommended by EPA. Many of the salts of nickel and tin are soluble in water. They may be more hazardous to aquatic life than their parent ions because of their higher level of toxicity.

In soft water, concentrations of zinc ranging from 0.1 to 1.0 mg/l have been reported to be lethal to fish. Zinc is thought to exert its toxic action by forming insoluble compounds with the mucus that covers the gills, by damage to the gill epithelium, or possibly by acting as an internal poison (McKee, 1971, ref. 1972). The sensitivity of fish to zinc varies with species, age, and condition, as well as with the physical and chemical characteristics of the water. Some acclimation to the presence of zinc is possible. It has also been observed that the effects of zinc poisoning may not become apparent immediately, so that fish moved from zinc-contaminated (after 4 to 6 hours of exposure) to zinc-free water may die 48 hours later. The presence of copper in water may increase the toxicity of zinc to aquatic organisms, while the presence of calcium or hardness may decrease the relative toxicity. EPA has recommended a limited application factor of 0.01 of the 96 hour LC 50 (lethal concentration for 50 percent of the organisms) for freshwater life (US EPA, 440/9-76-023, 9/76, ref. 407). The metals listed above can be analyzed in waste waters by either wet chemical or atomic absorption methods of analysis (WPCF, 1975, ref. 456).

Pollutants of Secondary Significance

Nutrients

Aquatic nutrients in this context are various forms of phosphorus and nitrogen. Both these elements are essential to aquatic organisms. They are, however, often the limiting nutrients in natural waters. An excess of these elements in a form that can be assimilated by aquatic organisms may lead to eutrophication of surface waters.

An increase in the supply of phosphorus leads to increasing standing crops of aquatic plant growths, which often interfere with water uses and are nuisances to man. Such phenomena are associated with a condition of accelerated eutrophication or aging of waters. It is generally recognized that phosphorus is not the sole cause of eutrophication, but there is evidence to indicate that it is frequently the key element required by fresh water plants and is generally present in the least amount relative to need in nature. Therefore, an increase in phosphorus allows the use of other already present nutrients for plant growths. For this reason, phosphorus is usually described as a "limiting nutrient" (US EPA, 440/9-76-023, 9/76, ref. 407).

When plant life is stimulated and attains a nuisance status, a large number of associated liabilities are immediately apparent. Growths of pond weeds make swimming dangerous. Boating, water skiing, and sometimes fishing may be eliminated because the mass of vegetation physically impedes such activities. Dense plant populations have been associated with stunted fish populations and poor fishing. Decaying nuisance plants emit vile odors, impart tastes and odors to water supplies, reduce the efficiency of industrial and municipal water treatment, impair aesthetic beauty, reduce or restrict resort trade, lower waterfront property values, cause skin rashes to man during water contact, and serve as a substrate and breeding ground for flies and other insects.

Phosphorus concentrations in waste waters are measured by a colorimetric procedure. Pretreatment of the sample before analysis allows the measurement of various forms of phosphorus including orthophosphate, organic phosphates, complex phosphates and total phosphorus, (WPCF, 1975, ref. 456). In thoroughly assessing the potential of a waste water to contribute to eutrophication, all these measurements should be made. However, soluble orthophosphate concentrations are considered to be the single most important parameter in measuring nutrients. The orthophosphate species are the most readily available to aquatic plants and the most likely to cause water quality problems. Total phosphorus measurement is the second most useful parameter in measuring nutrients since it defines the ultimate amount of the nutrient that may become available to aquatic plants under the most severe natural conditions.

Nitrogen compounds of concern include ammonia, nitrate, nitrite, and organic nitrogen. Ammonia is a common product of the decomposition of organic matter. Dead and decaying animals and plants along with human and animal body wastes account for much of the ammonia entering the aquatic ecosystem. Industrial waste waters are another major source.

Ammonia is a form of nitrogen that readily fulfills the nutrient requirement of aquatic plants. In those cases where adequate phosphorus is available, nitrogen may be the limiting nutrient. In such a case, the discharge of waste waters containing ammonia will contribute to eutrophication of the receiving water and consequent nuisance aquatic plant growth. Ammonia can also be toxic to aquatic animals (US EPA, 440/9-76-023, 9/76, ref. 407).

The toxicity of ammonium solutions is dependent upon the amount of ammonia, the concentrations of which vary with the pH of the water. In most natural waters the pH range is such that ammonium ions predominate; however, in alkaline waters high concentrations of ammonia increase the toxicity. EPA has recommended a maximum acceptable concentration of ammonia of 0.02 mg/l in waters suitable for aquatic life (US EPA, 440/9-76-023, 9/76, ref. 407).

In natural waters containing dissolved oxygen, ammonia is converted to nitrate by nitrifying bacteria. Nitrite, which is an intermediate product between ammonia and nitrate, sometimes occurs in large quantities when depressed oxygen conditions permit. Both nitrate and nitrite are aquatic plant nutrients but they are not as readily assimilated as ammonia, (Wetzel, 1975, ref. 440).

Excessive concentrations of nitrate in waters can cause methemoglobinemia in human infants. Nitrate has been limited by the United States Public Health Service to 10 mg/l as nitrogen in public water supplies (WPCF, 1975, ref. 450).

Ammonia concentrations in waste water may be determined by colorimetric or specific ion electrode methods. Nitrate and nitrite are determined colorimetrically. Organic nitrogen concentrations may be determined by the Kjeldahl procedure, by which organic nitrogen is reduced chemically to ammonia which is determined colorimetrically (WPCF, 1975, ref. 456).

In the pesticide industry ammonia nitrogen may be generated up to levels of 1,500 mg/l at individual plants. Ammonia is not a universal pollutant for this industry and should be controlled as necessary on an individual basis.

Phenols

Phenols and phenolic compounds are a potential waste water constituent in the pesticide chemicals industry, particularly the manufacture of halogenated organic pesticides. Because it is not universally present in this category it should be controlled as necessary on an individual basis.

Many phenolic compounds such as tetra-chlorodibenzo-p-dioxin are more toxic than pure phenol; their toxicity varies with the combinations and general nature of total wastes. The effect of combinations of different phenolic compounds is cumulative.

Phenols and phenolic compounds are both acutely and chronically toxic to fish and other aquatic animals. Also, chlorophenols produce an unpleasant taste in fish flesh, destroying their commerical value. EPA has recommended a limit of 1 ug/l of phenol in fresh water (USEPA, 440/9-76-023, 9/76, ref. 407).

It is necessary to limit phenolic compounds in the raw water used for supplying drinking water, as conventional treatment methods used by water supply facilities do not remove phenols.

Disinfection of drinking water with chlorine when phenol is present even at very low concentrations, forms chlorophenols, producing taste and odor problems (WPCF, 1975, ref. 456).

Phenols also reduce the utility of water for certain industrial uses, notably food and beverage processing, where it creates unpleasant tastes and odors in the product. Phenols may be determined in waste waters by colorimetric methods of analysis.

Cyanide

Of all the cyanides, hydrogen cyanide (HCN) is probably the most acutely lethal compound. HCN dissociates in water to hydrogen ions and cyanide ions in a pH dependent reaction. The cyanide ion is less acutely lethal than HCN. The relationship of pH to HCN shows that as the pH is lowered below 7, less than 1 percent of the cyanide molecules in the form of the CN ion are present and the rest are present as HCN. When the pH is increased to 8, 9, and 10, the percentage of cyanide present as CN ion is 6.7, 42, and 87 percent, respectively. The toxicity of cyanides is also increased by elevations in temperature and reductions in oxygen concentrations. A temperature rise of 10°C produced a two- to threefold increase in the rate of the lethal action of cyanide (US EPA, 440/9-76-023, 9/76, ref. 407).

In the body, the CN ion, except for a small portion exhaled, is rapidly changed into a relatively non-toxic complex (thiocyanate) in the liver and eliminated in the urine.

There is no evidence that the CN ion is stored in the body, (McKee, 1971, ref. 192). The level of cyanide which can be safely ingested has been estimated at something less than 18 mg/day. The average fatal dose of HCN by ingestion by man is 50 to 60 mg. EPA has been recommended a limit of 0.2 mg/l cyanide in public water supply sources.

The harmful effects of the cyanides on aquatic life are affected by the pH, temperature, dissolved oxygen content, and the concentration of minerals in the water. The biochemical degradation of cyanide is not affected by temperature in the range of 10 to 35° C, while the toxicity of HCN is increased at higher temperatures.

Cyanide does not seem to be as toxic to lower forms of aquatic life as it is to fish. The organisms that reduce BOD were found to be inhibited at between 1.0 mg/l and 60 mg/l although the effect is more one of delay in exertion of BOD than total reduction.

Certain metals such as nickel may complex with cyanide to reduce toxicity, especially at higher pH values. On the other hand, zinc and cadmium cyanide complexes may be exceedingly toxic (US EPA, 440/9-76-023, 9/76, ref. 407).

Cyanide is not universally present in pesticide chemicals wastes and should be controlled as necessary on an individual basis.

Other Pollutants

Settleable solids can be harmful to the aquatic environment in the same manner as suspended solids. Measurement of total suspended solid (TSS) includes both the suspended and settleable solids.

The quantity of total dissolved solids in waste water is of little meaning unless the nature of the solids are defined. In fresh water supplies, dissolved solids are usually inorganic salts with small amounts of dissolved organics, and total concentrations may often be several thousand milligrams per liter. It is not considered necessary to recommend limits for total dissolved solids since they are limited by other parameters, such as BOD, COD, and TSS.

Acidity is produced by substances that yield hydrogen ions upon hydrolysis, and alkalinity is produced by substances that yield hydroxyl ions. The terms "total acidity" and "total alkalinity" are often used to express the buffering capacity of a solution.

Alkalinity in water is primarily a measure of hydroxide, carbonate, and bicarbonate ions. Its primary significance in water chemistry is its indication of a water's capacity to neutralize acidic solutions. In high concentrations, alkalinity can cause problems in water treatment facilities. However, by control of pH, alkalinity is also controlled.

Acidity in natural waters is caused by carbon dioxide, mineral acids, weakly dissociated acids, and the salts of strong acids and weak bases.

Chlorides can cause detectable taste in drinking water in salt (e.g., sodium, calcium, manganese) concentrations greater than about 150 mg/l; however, the concentrations are not toxic. Drinking water standards are generally based on palatability rather than health requirements. A consideration to irrigate crops with waste water should take into account chloride concentrations as the salts generally inhibit the growth of vegetation.

Extremely high chloride concentrations can cause difficulty in biological treatment. However, the successful acclimation of activated sludge organisms to high chloride concentrations has been demonstrated by several pesticide chemicals plants, as well as a number of municipal treatment systems, in areas of high saline water infiltration into sewers. Several pesticide plants report chloride concentrations as high as 10,000 to 20,000 mg/l.

Oil and grease may result from various solvents used in processing operations, spills or leaks of fuel oils, and losses of lubricating fluids. These compounds may settle or float and may exist as solids or liquids. Even in small quantities, oil and grease may cause taste and odor problems in water. In natural waters they can affect aquatic life adversely and exert an oxygen demand.

Oil and grease have not been observed to be a particular problem in the pesticide chemicals industry in those cases where adequate solvent recovery is practiced. As in any industry, oil and grease in pesticide wastewaters must be controlled by good in-plant operations.

Sulfides can exert an oxygen demand on receiving streams, impart an unpleasant taste and odor, and render the water unfit for other use. Except in extreme cases, sulfides are controlled by the same mechanisms used to control organics and suspended solids.

Conclusion

It is concluded from the discussion above that for purposes of treatment control, for the elimination of adverse environmental effects, and for the documentation of particular previously undefined compounds in effluents, that BOD, COD, TSS, pesticide chemicals and pH should be regulated for this industry, and that phenol, ammonia, and cyanide should be examined on a case-by-case basis.

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

This section identifies the range of control and treatment technologies currently practiced in the industry. A detailed review is presented of full-scale design and operating characteristics of the two most frequently utilized pesticide removal technologies, activated carbon and hydrolysis. Also included is a summary of pertinent literature. This section documents the final effluent levels being achieved by the various treatment technologies employed at plants in the industry. The components are also defined for the model treatment technology which is utilized as the basis of cost calculations in Section VIII.

The data relating to treated effluents that are presented in this section form the basis for the derivation of effluent limitations guidelines in Section IX. The treatment technologies presented, pesticide removal through the application of activated carbon or hydrolysis technology, equalization, and biological treatment, represent one of the several treatment schemes capable of meeting the effluent limitations.

The Agency does not require that any specific technology(ies) be employed; the requirement is that promulgated effluent limitations be attained. However, in order to evaluate the economic impact associated with the implementation of the standards, model treatment systems are costed for each subcategory. The installation of well-designed and operated treatment systems, similar to the model treatment technologies, will result in attainment of the recommended standards.

Personnel at each facility must decide which specific control measures are best suited to its situation and needs. It is not good practice for industrial waste water treatment facilities to be designed without conducting treatability studies to determine the optimum design, nor is it good practice that monies be budgeted without conducting an economic assessment of the various applicable technologies.

It should be emphasized that the treatment technologies selected for the basis of cost estimates are not the only systems capable of attaining the specific effluent limitations. However, the recommended effluent limitations can be attained through the application of the unit operations presented in this section.

Preceding page blank

INDUSTRY TREATMENT PROFILE

Tables VII-1 and VII-2 present the types of production, methods of waste water disposal, and types of treatment technologies employed by the direct and indirect dischargers respectively in the pesticide chemicals manufacturing industry.

An examination of Table VII-1 and subsequent individual plant discussions will show that a majority of the direct dischargers currently employ pollution reduction techniques equivalent to those which form the basis of the cost estimates. A plant by plant analysis of the additional costs required for direct dischargers to meet BPT is presented in Section IX.

Subcategory 1 - Organic Pesticide Chemicals

PESTICIDE REMOVAL TECHNOLOGY REVIEW

Since Interim Final regulations were published on November 1, 1976, a comprehensive review of activated carbon and hydrolysis pesticide removal technologies was conducted. This study was used to verify and/or supplement existing design and operating data concerning these systems and to make appropriate changes to the effluent limitations and cost analyses included in the previous development document. Additional sampling and analysis was undertaken by both the EPA contractor and the plants involved. The following discussions present the results of this review.

Activated Carbon

Activated carbon has been used for many years for removing color and odors from various aqueous streams (i.e., sugar refining). Adsorption of a molecule within the porous structure of the activated carbon granule is affected by a variety of factors including molecular size of the adsorbate, solubility of the adsorbate, pore structure of the carbon and other factors as discussed in the following paragraphs.

For sorption to occur, the adsorbate molecule must first travel from the bulk solution to the surface of the carbon. Once at the surface, it must diffuse into the inner pores of the carbon where most of the binding sites are contained. Finally the adsorbate must align itself with the carbon surface to allow binding to occur.

Several parameters affect absorption. Diffusion of the adsorbate from the bulk solution to the surface of the carbon occurs by two mechanisms, molecular and eddy diffusion.

TABLE VII-1

DIRECT DISCHARGER PROFILE
PESTICIDE INDUSTRY

PLANT	PRODUCTION CATEGORY							METHODS OF WASTEWATER DISPOSAL				TYPES OF TREATMENT														
	A	B	C	D	E	F	G	1	2	3	4	Ac	Co	Ev	Hd	Ie	Mf	Ra	Sp	Eq	Sk	Gs	As	Al	Tf	Ne
3	X	-	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	-	X
8	X	-	-	-	-	-	X	X	-	-	-	X	-	-	-	-	-	-	-	X	-	-	-	-	-	X
9	X	-	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	X
11	X	-	-	-	-	-	X	X	X[1]	-	-	-	-	-	-	-	-	-	X	-	-	X	-	-	-	X
15	X	-	-	-	-	-	X	X	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	X
16	X	-	-	-	X	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
18	X	X	X	-	X	-	X	X	-	-	-	X	-	-	-	-	-	X	-	-	-	X	-	-	-	X
19	X	-	-	X	X	-	X	X	-	-	-	X	-	-	-	-	X	-	-	X	-	X	X	-	-	X
21	X	X	X	-	X	-	X	X	-	-	-	-	-	-	X	-	-	-	-	X	-	X	-	X	-	X
22	X	X	X	-	X	-	X	X	X	X	-	X	-	-	-	-	-	-	-	X	-	X	X	-	X	X
27	-	X	-	-	-	-	X	X	-	-	-	-	-	-	X	-	-	-	-	-	-	X	-	X	-	X
29	-	X	-	-	-	-	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X
31	-	X	-	-	-	-	X	X	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	X
32	-	X	X	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	X	-	X	X	-	-	X
33	-	X	X	-	X	-	X	X	X[1]	-	-	-	-	-	-	-	-	-	-	X	-	-	X	X	-	X
34	X	X	X	-	X	-	-	X	-	X	-	-	-	-	X	-	-	-	X	X	X	X	-	X	-	X
36	-	-	X	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
39	-	-	X	-	X	-	X	X	-	X	-	X	-	-	-	-	-	-	-	X	-	X	X	-	-	X
40	-	-	X	-	X	X	X	X	X[1]	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-	X
41	-	-	X	-	X	-	-	X	-	X[1]	-	-	-	-	-	-	-	-	-	X	-	-	X	-	-	X
45	-	-	X	-	X	X	X	X	-	-	-	X	-	-	-	-	X	-	-	-	-	X	-	-	-	X
47	-	-	X	-	X	-	X	X	-	-	-	-	-	-	-	-	-	-	-	X	-	X	X	-	-	X
48	-	-	X	X	X	-	X	X	-	X	-	-	X	-	-	-	-	-	-	X	-	X	-	X	-	X
50	-	-	X	X	X	-	-	X	-	-	-	X	-	X	-	X	X	-	-	X	-	X	-	-	-	X
53	-	-	-	X	X	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	X
139	-	-	-	-	-	X	X	X	-	-	-	-	-	-	-	-	-	-	-	X	-	X	X	-	X	X
146	X	-	X	-	-	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	X	X	X
149	-	-	X	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	X
155	-	-	X	-	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note: [1] Method of disposal utilized by plant for products not covered by this regulation.

CODES:

PRODUCTION CATEGORY:

A. Halogenated Organics
B. Organo Phosphorus
C. Organo Nitrogen
D. Metallo Organic
E. Formulators/Packagers
F. Non-Categorized Pesticides
G. Non-Pesticide Products

METHODS OF WASTEWATER DISPOSAL:

1. Direct Discharger
2. Deep Well Injection
3. Incineration
4. Contract Truck Hauling

TYPES OF TREATMENT:

Ac = Activated Carbon
Co = Chemical Oxidation
Ev = Multiple Effect Evaporation
Hd = Hydrolysis
Ie = Ion Exchange
Mf = Multi-Media Filtration
Ra = Resin Absorption
Sp = Stripping
Eq = Equalization
Sk = Skimming
Gs = Gravity Separation
As = Activated Sludge
Al = Aerated Lagoon
Tf = Trickling Filters
Ne = Neutralization

TABLE VII-2

INDIRECT DISCHARGER PROFILE
PESTICIDE INDUSTRY

	PRODUCTION CATEGORY										METHODS OF WASTEWATER DISPOSAL									TYPES OF TREATMENT																					
PLANT	A	B	C	D	E	F	G	H	I	J	1	2	3	4	5	6	7	8	9	Ac	Ca	Ep	Fo	Hd	Mf	Ra	Ch	Dh	Eq	Sk	Gs	As	Al	Ne	Ad	St	Vf	Ms	Ws	No	Uk
1	X	-	-	-	X	-	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X	X	-	-	-	-	-	-	-
4	X	-	-	-	-	-	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	-	-
5	X	-	X	-	-	-	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
6	X	-	-	-	X	-	-	-	-	X	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-
7	X	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
10	X	-	-	-	X	-	-	X	X	X	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	X	-	-	-	X	-	-	-	-	X	-	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
13	X	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	-	-	-	-	-	-
14	X	X	-	X	X	-	-	X	X	X	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	X	-	X	X	-	-	X	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	X	-	-	-	X	-	-	-	-	-	-	-
23	X	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	X	-	X	X	-	-	X	-	X	-	-	-	-	-
24	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
25	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
26	X	-	-	-	X	-	-	X	-	X	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
28	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	X	-	-	-	-	-	-	X	-	-	-	-	X	-	X	X	-	X	-	X	X	-	-	-	-
30	-	X	X	-	-	X	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
35	-	X	-	-	X	-	-	X	X	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
37	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
38	-	-	X	X	-	-	X	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	-	X	X	-	-	-	-	-	-	-
43	-	-	X	-	-	-	-	-	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-
44	-	-	X	-	X	-	-	X	-	-	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
46	-	-	X	-	X	-	-	-	-	X	X	-	-	-	-	-	-	-	-	X	-	-	-	-	X	-	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-
51	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
52	-	-	X	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
54	-	-	X	X	X	-	X	X	X	X	X	-	-	-	-	-	-	-	-	-	X	-	X	-	X	-	-	-	-	-	X	-	-	-	-	-	-	X	-	-	-
55	-	-	-	X	X	-	X	-	X	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	X	-	-
56	-	-	-	X	-	-	X	-	-	-	-	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
57	X	-	-	X	X	-	-	X	-	X	X	-	-	X	X	-	X	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	X	X	-	-	-	-	-	-
58	X	-	X	X	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
59	-	-	-	-	X	-	-	X	-	X	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
60	-	-	-	-	X	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
61	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
62	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
63	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
64	-	-	-	-	X	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
65	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
66	-	-	-	-	X	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
67	-	-	-	-	X	-	-	X	X	X	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
68	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
69	-	-	-	-	X	-	-	X	X	X	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
70	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
71	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
72	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
73	-	-	-	-	X	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
74	-	-	-	-	X	-	-	X	-	X	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
75	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-

TABLE VII-2
Continued
Page 2 of 4 Pages

PLANT	PRODUCTION CATEGORY										METHODS OF WASTEWATER DISPOSAL									TYPES OF TREATMENT																					
	A	B	C	D	E	F	G	H	I	J	1	2	3	4	5	6	7	8	9	Ac	Ca	Ep	Fo	Hd	Mf	Ra	Ch	Dh	Eq	Sk	Gs	As	Al	Ne	Ad	St	Vf	Ms	Ws	No	Uk
76	-	-	-	-	X	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
77	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
78	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
79	-	-	-	-	X	-	-	X	X	X	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
80	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
81	-	-	-	-	X	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
82	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
83	-	-	-	-	X	-	-	X	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
84	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
85	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
86	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
87	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
88	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
89	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
90	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
91	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
92	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
93	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
94	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
95	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
97	-	-	-	-	X	-	-	X	-	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
98	-	-	-	-	X	-	-	X	X	X	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
99	-	X	-	-	-	X	-	X	X	X	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
100	-	X	-	-	-	X	-	X	X	X	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
101	-	-	-	-	X	-	-	X	X	-	X	-	-	X	-	-	-	-	-	X	X	-	X	-	-	-	-	-	-	X	-	-	X	X	-	-	X	-	-	-	-
102	-	-	-	-	X	-	-	X	X	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
103	-	-	-	-	X	-	-	X	X	X	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
104	-	-	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
105	-	-	-	-	X	-	-	-	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
106	-	-	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
107	-	-	-	-	X	-	-	X	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
108	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
109	-	-	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
110	-	-	-	-	X	-	-	X	-	-	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
111	-	-	-	-	X	-	-	X	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
112	-	-	-	-	X	-	-	X	X	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
113	-	-	-	-	X	-	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
114	-	-	-	-	X	-	-	X	X	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
115	-	-	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
116	-	-	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
117	-	-	-	-	X	-	-	X	X	X	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
118	-	-	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
119	-	-	-	-	X	-	-	X	X	X	X	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
120	-	-	-	-	X	-	-	-	X	X	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
121	-	-	-	-	X	-	-	X	X	-	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
122	-	-	-	-	X	-	-	X	X	-	X	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-

TABLE VII-2
Continued
Page 3 of 4 Pages

PLANT	PRODUCTION CATEGORY										METHODS OF WASTEWATER DISPOSAL									TYPES OF TREATMENT																					
	A	B	C	D	E	F	G	H	I	J	1	2	3	4	5	6	7	8	9	Ac	Ca	Ep	Fo	Hd	Mf	Ra	Ch	Dh	Eq	Sk	Gs	As	Al	Ne	Ad	St	Vf	Ms	Ws	No	Uk
123	-	-	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
124	-	-	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
125	-	-	-	-	X	-	-	X	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
126	-	-	-	-	X	-	-	-	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
127	-	-	-	-	X	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
128	-	-	-	-	X	-	-	X	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
129	-	-	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
130	-	-	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
131	-	-	-	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
132	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
133	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
134	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
135	-	-	-	-	-	X	-	-	-	-	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
136	-	-	-	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-
137	-	-	-	-	X	X	-	-	-	-	-	-	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
138	-	-	-	-	X	X	-	-	X	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
140	-	-	-	-	X	X	-	X	X	X	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
141	-	-	-	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
142	-	-	-	-	-	-	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
143	-	-	-	-	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
144	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
145	X	-	X	-	X	X	X	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
147	-	-	-	-	X	-	X	X	X	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
148	-	X	-	-	-	-	X	-	-	-	-	-	X	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-
151	X	X	-	-	-	X	-	X	-	-	-	-	X	-	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	-	X	X	-	-	-	-	-	-	-	-
152	X	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
153	-	-	X	-	-	-	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-
154	-	-	X	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-
156	-	-	X	-	X	-	X	-	-	X	-	-	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
157	-	-	X	-	-	X	X	-	-	-	-	-	-	-	X	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
158	X	-	-	X	X	X	-	-	-	X	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-
159	-	-	-	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
160	-	-	-	-	X	-	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
161	-	-	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
162	-	-	X	-	X	-	-	X	-	-	-	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE VII-2
Continued
Page 4 of 4 Pages

CODES:

PRODUCTION CATEGORY:

A. Halogenated Organics
B. Organo Phosphorus
C. Organo Nitrogen
D. Metallo Organic
E. Formulators/Packagers
F. Non-Categorized Pesticides
G. Non-Pesticide Products
H. Solvent Formulation
I. Wet Formulation
J. Dry Formulation

METHODS OF WASTEWATER DISPOSAL:

1. Municipal
2. Direct
3. Other
4. Land
5. Truck Hauling
6. Ocean Discharge
7. Incineration
8. Deep Well Injection
9. No Wastewater Generated

TYPES OF TREATMENT:

Ac = Activated Carbon
Ca = Coagulation
Ep = Evaporation Pond
Fo = Floculation
Hd = Hydrolysis
Mf = Multi-Media Filtration
Ra = Resin Absorption
Ch = Chlorination
Dh = Dehydrochlorination
Eq = Equalization
Sk = Skimming
Ga = Gravity Separation
As = Activated Sludge
Al = Aerated Lagoon
Ne = Neutralization
Ad = Aerobic Digestor
St = Sludge Thickening
Vf = Vacuum Filtration
Ms = Metal Separation
Ws = Wet Scrubber
No = None
Uk = Unknown

Molecular diffusion has a very strong dependency on temperature. For example, the diffusivity of a component in water at 100°F is 50 percent greater than that for the same component at 70°F.

Eddy diffusion results from transport of the adsorbate molecules due to turbulent eddies. This phenomenon occurs only in turbulent flow and is effective up to the laminar boundary layer near the surface of the carbon granule. Eddy diffusion also increases with increased temperature. Both are caused by lower viscosity as a result of the higher temperature resulting in better contact with the activated sites.

The molecular diameter and structure of the adsorbate molecule are also important factors in determining the adsorption characteristics of the solute. Obviously, the molecule must physically be able to diffuse into the internal pores of the carbon. Finally, a major factor in determining the adsorption characteristics of a given solute is its solubility in the waste water. This, presumably, is the reason for the strong influences of pH on the adsorption of many molecules.

Full Scale Activated Carbon Treatment Data. There are ten full-scale carbon systems currently employed or under design in subcategory 1. Nine are used to reduce pesticide chemicals in the waste stream and one is used to reduce chlorine. Design data for these systems are found in Table VII-3. From a review of this table and the accompanying text it is apparent that under proper pH and contact time conditions, activated carbon is highly effective in removing pesticides from waste water.

Activated carbon has been applied primarily to halogenated organic and organo-nitrogen compounds. The effectiveness of column configuration has been determined on an empirical basis (i.e., Plants 6, 8, and 45 have experimented with counterflow systems). Long contact times and low loading rates are being utilized at some facilities to insure high removals of pesticide active ingredients. For the most part, the pH of the process water has not been adjusted, nor has extensive testing been conducted in order to optimize the system. Few plants are known to practice backwashing.

A weekly air scouring is utilized at Plant 45 in order to prevent channeling and to remove suspended matter. Plants 45 and 46 employ sand filters used in advance of the carbon columns in order to improve bed life and to remove solids that could plug the column. In several cases, carbon replacement is based on administrative decision rather than maximum pesticide removal.

TABLE VII-3

ACTIVIATED CARBON DESIGN SUMMARY
PESTICIDE INDUSTRY

PLANT	PRODUCT(S)	COLUMN CONFIGURATION	CONTACT TIME (MIN)	pH	SLR (GPM/FT2)	LBS. CARBON/ KGAL TREATED	TYPE REGENERATION-SYSTEM
6	2,4-D 2,4-DB MCPA MCPB Bromoxynil Octanoate	Upflow	760	1	0.60	110	Thermal-Owned
8	PCNB	Downflow	479	0.5-4.0	0.32	127	Thermal-Lease
18	Toxaphene DNBP Cyanazine	NA	NA	NA	NA	NA	NA
20	Dicofol	Downflow	35	0.5	2.10	NA	Isopropanol-Owned
22	Dalpon	NA	NA	NA	NA	NA	NA
39	Trifluralin Isopropalin Ethalfluralin	Downflow	230	9.0	0.66	154	Thermal-Lease
45	DEET Piperonyl Butoxide Thanite	Downflow	456	4-5	0.36	21.1	Thermal-Lease
46	Atrazine	Downflow	120	8-12	1.3	7.8	Thermal-Lease
50	Carbofuran	Downflow	292	7-9	0.51	207	Thermal-Lease

SLR = Surface Loading Rate
NA = Not Available

Although flow rates have not been presented, it is important to note that activated carbon has usually been applied to low flow, segregated, and concentrated waste streams as a pretreatment technology. Flows between 1,000 and 150,000 gal/day have been observed to be pretreated using activated carbon. Personnel at plant 18 are designing a tertiary carbon system wherein contact time, loading rate, and carbon usage would be expected to vary considerably from the levels depicted in Table VII-3.

With the exception of plants 20 and 46, pesticide removals in excess of 99 percent are being consistently achieved (Table VII-4). Plants 20 and 46 operate the carbon to predetermined discharge levels before either back rinsing with solvent or changing the carbon. Other plants (e.g. Plants 45 and 50) have contracts with carbon suppliers and operate the carbon columns until the supplier changes the carbon according to schedule.

Removal of organic pollutants is a significant benefit in employing activated carbon, and in most cases the initial design of existing columns was based on TOC, rather than pesticide reduction. Utilizing activated carbon generally decreases the size of subsequent biological treatment processes required. This is shown in Table VII-4.

At Plant 6, five organic pesticide chemicals are produced: 2,4-D, 2,4-DB, MCPA, MCPB, and bromoxynil octonoate. Waste water from these processes enters an 8,000 gallon surge tank at pH 1.5, passes in series up through two 18,000 gallon wooden tanks charged with 15,000 pounds of carbon, is neutralized with lime to pH 6.0 - 8.0, and then goes to a 20,400 gallon holding tank prior to discharge. Table VII-4 gives the results of sampling conducted by the EPA contractor while the plant was producing 2,4-D, esters, and dichlorophenol.

At Plant 8 PCNB(parachloronitrobenzene) waste water is treated using activated carbon. 20,000 lb adsorbers are operated downflow in series at pH 0.5 to 4.0. The effluent is neutralized and discharged to a navigable waterway. Data is presented in Table VII-4 for periods when PCNB was produced both solely and together with terrazole. Both are halogenated compounds.

At Plant 19, DCPA, chlorothalonil and an intermediate, chloral, are produced. The plant operates a carbon column but the purpose is to remove chlorine from the waste stream not pesticide chemicals. No known pesticide chemicals are reported removed by this unit.

At Plant 20 dicofol is produced. Although the waste water is discharged to a public treatment system, dicofol is pretreated in

TABLE VII-4

ACTIVATED CARBON TREATMENT SUMMARY
PESTICIDE INDUSTRY

		BOD			COD			TOC		
PLANT	PRODUCT(S)	INF. mg/l	EFF. mg/l	% REMOVAL	INF. mg/l	EFF. mg/l	% REMOVAL	INF. mg/l	EFF. mg/l	% REMOVAL
6	2,4-D	1630	780	52.1	5780	2120	63.2	2220	534	76.0
8	PCNB	NM	NM	N/A	5770	320	94.4	698	85.7	97.7
	Terrazole	NM	NM	N/A	5770	320	94.4	698	85.7	97.7
20	Dicofol	45200	37400	17.4	148000	109000	26.7	79800	66700	16.4
39	(1) Trifluralin	995	1100	N/A	8310	6380	23.3	926	1950	N/A
	(2) Trifluralin	301	109	63.8	8290	1394	83.2	1665	291	82.5
45	DEET	NM	889	N/A	4750	808	82.9	1650	153	90.7
	Piperonyl Butoxide	NM	889	N/A	4750	808	82.9	1650	153	90.7
46	Atrazine	NM	NM	N/A	NM	NM	N/A	NM	NM	N/A
50	Carbofuran	193	9.2	95.2	4880	31.2	99.4	2170	15.4	99.3

		TSS			TOTAL PHENOL			PESTICIDES		
PLANT	PRODUCT(S)	INF. mg/l	EFF. mg/l	% REMOVAL	INF. mg/l	EFF. mg/l	% REMOVAL	INF. mg/l	EFF. mg/l	% REMOVAL
6	2,4-D	69	109	N/A	77.9	2.32	97.0	58.4	0.037	99.9
8	PCNB	1510	255	83.1	NM	NM	N/A	11.6	0.0093	99.9**
	Terrazole	1510	255	83.1	NM	NM	N/A	NM	NM	N/A
20	Dicofol	1460	2600	N/A	NM	NM	NN/A	17.2	10.5	39.1
39	(1)Trifluralin	168	165	1.8	2.02*	0.51*	74.8	11.3	0.104	99.1
	(2)Trifluralin	312	2.8	99.1	NM	NM	N/A	3.37	0.004	99.9
45	DEET	68.6	46.6	31.8	129	4.26	96.7	218	1.26	99.4
	Piperonyl Butoxide	68.6	46.8	31.8	129	4.26	96.7	7.57	0.01*	99.9**
46	Atrazine	29.5	8.78	70.2	NM	NM	NM	18.9	2.46	86.9
50	Carbofuran	674	6.6	99.0	0.28	0.7*	75.0**	2250	0.46	99.9

(1) EPA Analytical Results
(2) Plant Analytical Results

* = Less Than
**= Greater Than

an activated carbon system prior to discharge. The raw waste is collected in a 1,000 gallon surge tank, passed through columns (2 feet in diameter by 10 feet high) and stored until analysis has been completed. If the total of all chlorinated pesticide chemicals is less than 5 mg/l, the waste water is discharged to the municipal treatment system. If not, it is recycled through the columns again. The carbon is regenerated with isopropanol and the solvent is incinerated. Carbon is replaced infrequently, approximately twice per year. This system is inefficient because of the small detention time and the necessity for more frequent fresh carbon addition. Low flows allow frequent recycle in order that their effluent objective be met. Table VII-4 presents five and one-half months of pesticide data by the plant, six days BOD, COD, TOC, TSS, and pesticide chemicals data by the plant, and seventeen days of sampling analyzed by the EPA contractor.

Plant 22 submitted one data point (0.24 kg/kkg) representing the average of seven days sampling from the effluent of dalapon waste water. Neither the operating conditions of the activated carbon system nor the individual analyses have been supplied by representatives of the plant.

At Plant 39 waste water from trifluralin, ethalfluralin, and benfluralin is treated using activated carbon. These compounds are nitrogen-based pesticide chemicals. Process water at pH 8.5 to 9.5 flows through two 20,000 pound adsorbers in series and is combined with other plant waste water in a biological system. Table VII-4 presents data analyzed by both the EPA contractor and the plant.

At Plant 45 waste water from DEET, piperonil butoxide, and several non-pesticide products is treated (See Table VII-4). Raw waste water enters a 250,000 gallon equalization basin where the pH is adjusted to 5.0 to 6.0. It is then passed through a dual media filter and stored in a 100,000 gallon equalization pond. Two 20,000 pound carbon columns operated downflow in-series, a 100,000 gallon, and a 250,000 gallon equalization ponds comprise the remainder of the treatment system prior to discharge to navigable waters.

Table VII-4 shows Plant 46 produces atrazine. Waste water from this plant enters a sump and is pumped to two 0.5 million gallon holding tanks in series. Overflow proceeds through two multi-media filters in parallel, each being four feet in diameter. Filtered waste water is passed downward through two 20,000 pound adsorbers in series, neutralized, clarified, and discharged to a municipal treatment plant. Carbon in the columns is changed only if the effluent level of atrazine exceeds 10 mg/l.

At Plant 50 floor washwater from a carbofuran process is treated using activated carbon (See Table VII-4). As such, this waste water is weaker than the wastes from other pesticide manufacturing operations and is not representative of the industry. Washwater at pH 7.0 - 9.0 is stored in a 6,000 gallon tank. For a period of two to three hours daily the waste water is passed downward through two 20,000 pound carbon columns in series. The effluent is currently discharged to a holding pond and is subsequently reused as washdown water.

Activated Carbon Dynamic Data and Isotherm Data. Isotherm and dynamic data from the literature and Agency correspondence are summarized in Table VII-5. These data expand and/or supplement the documentation of carbon applicability to the following groups of pesticides: alkanoic acids, DDT and relatives, halogenated aromatics, phosphorothioates, amides, carbamates, nitros, ureas, and triazines.

Dynamic carbon data are data obtained from pilot or spill prevention operations. The units are generally portable and are used to predict full scale operating conditions. Dynamic data allow prediction of required contact times to achieve given reductions in pesticide levels as well as carbon regeneration rates.

The Oil and Hazardous Spills Branch of the U.S. EPA in Edison, New Jersey (Wilder, 1976), operates several mobile carbon columns which have been used to decontaminate various pesticide chemicals waste waters. Up to three columns are utilized in series at 100 to 600 gpm and 8 to 60 minutes contact time for a single pass or up to 240 minutes for recycled streams. The data in Table VII-5 for aldrin, chlordane, kepone, dieldrin, heptachlor, and toxaphene show extremely high removal efficiencies ranging from 97.2 to 99.99+ percent.

Eichelberger and Lichtenberg (1971) studied the sorption characteristics of a variety of organochlorine and organophosphorus pesticides using activated carbon. In each run a single pesticide was added to a sample of city tap water. The dynamic data for endosulfan and methoxychlor, included in Table VII-5, show a fairly good removal efficiency for methoxychlor of 89 percent (from 2 to 0.2 ug/l). The removal efficiency for endosulfan of 20 percent (from 2 to 1.6 ug/l) was not quite as good, but was reported to be sufficiently high to warrant further investigation using longer contact times, different carbons, or different pH.

Several investigators, including Eichelberger and Lichtenberg (1971) and Roebeck, (1965), have studied the adsorption characteristics of endrin. The dynamic column test data of Roebeck, et al., for which endrin was added to a sample of river water show a very high removal efficiency (greater than 99 percent) using a very short contact time of 7 1/2 minutes. Their data for dieldrin, although not presented here, corroborate those of Wilder (1976) for the same compound.

E.M. Froelich (1977) has presented data on the efficiency of activated carbon on actual pesticide chemicals waste streams. Pilot data are given along with the results of a full-scale treatment system. Of the compounds mentioned, all achieved levels of reduction of better than 99%. Original concentrations varied from 24 mg/l to 350 mg/l with effluent concentrations varying from less than 0.1 mg/l to less than 1.0 mg/l. Table VII-5 presents the results of these studies.

Sorption of 2,4,5-T using granular activated carbon columns was studied by Roebeck, et al. (1976). River water samples were spiked with single pesticide chemicals and mixtures of pesticides. Their data show better than 99 percent removal at a contact time of around 7.5 minutes (two columns in series). The investigation results for DDT and lindane show the same high removal efficiencies as for 2,4,5-T, as evidenced by the data presented in Table VII-5.

Lambden and Sharp (1960) reported on activated carbon treatment of industrial wastes for the removal of DNOC. Their data indicate that the reduction of DNOC from 60 mg/l to trace quantities with a 16-minute contact time (pH = 7 to 7.5).

Wilder (1976) has treated water contaminated with dinoseb and achieved extremely good results with a contact time of 26 minutes. This pesticide chemical was reduced from 8 ug/l to less than 0.02 ug/l, a removal efficiency of 99.75 percent.

Isotherms respresent adsorption under equilibrium conditions and indicate the maximum amount of a solute that will be adsorbed onto the carbon for any concentration of solute in the aqueous phase. This type of data is useful in selecting carbons for dynamic column tests and for estimating carbon regeneration rates. These tests do not account for diffusional effects that will occur under dynamic column conditions.

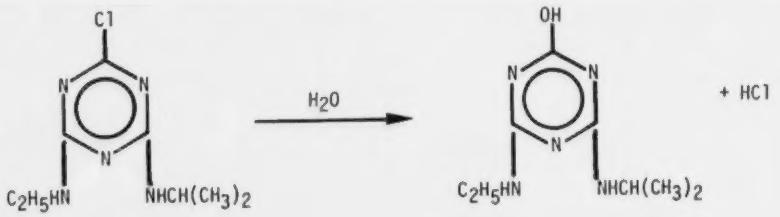
Isotherms for alachlor, propachlor, bromacil, and diuron (ESE, 1977) show extremely good adsorption characteristics. The data summarized in Table VII-5 show pickups ranging from 8 to 19 percent by weight for diuron and alachlor. The tests on these four compounds were conducted with distilled water using TOC as the control parameter.

Bernardin and Froelich (1975) gave results of their laboratory analysis of: aldrin, dieldrin, endrin, DDE, DDT, DDD, toxaphene, and aroclors 1242 and 1254. Procedural analysis consisted of the addition of varying amounts of individual pesticide chemicals to a specific quantity of activated carbon in a liter of solution. The pesticide carbon mixture was shaken four hours and filtered through a 0.45u millipore filter. The filtrate was then extracted and concentrated prior to analysis. Analysis was accomplished via gas-chromatograph techniques employing nickel-63 electron capture. Table VII-5 exhibits the results with the associated conditions.

In a study by Roebeck, et al. (1965), adsorption isotherms for dieldrin and lindane (among others) were obtained in samples of distilled water, river water, and river water containing more than one pesticide chemical. The isotherms show the effect that the presence of other organic compounds has on the sorption of a particular component. As expected, certain organics can occupy active sites on the carbon granule, thereby suppressing sorption of the pesticide chemical in question. This is evident on noting the decreased intercept (ug/mg). However, even in samples of river water, adsorption of lindane and dieldrin at very low concentrations was quite high.

Hydrolysis

In hydrolysis, a hydroxyl or hydrogen ion attaches itself to some part of the pesticide chemical molecule, either displacing part of the group or breaking a bond thus forming two or more new compounds. An example of the first type of reaction is found in the reaction between atrazine and water:



In this reaction, the chloride ion is displaced by the hydroxyl ion forming hydroxyatrazine and hydrogen chloride. Hydrolysis of diazinon provides an example of the second type of reaction:

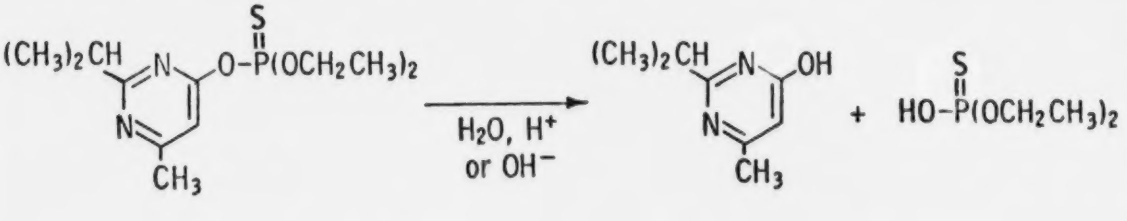


TABLE VII- 5

ACTIVATED CARBON ISOTHERM AND DYNAMIC DATA
PESTICIDE INDUSTRY

PESTICIDE	pH	CONTACT TIME. MIN.	INFLUENT CONC. PPB.	EFFLUENT CONC. PPB.	% REMOVAL
Aldrin	6.5-7.5	240	60.5	0.15	99.75
Chlorodane	6.5-7.5	17	8.5	0.19	97.76
Chlorodane	6.5-7.5	240	1430	0.43	99.99
Kepone	6.5-7.5	17	13	0.35	97.3
Dieldrin	6.5-7.5	45.5	4000	1*	99.98**
Dieldrin	6.5-7.5	240	60.5	0.01*	99.99**
Dieldrin	6.5-7.5	17	11	0.01*	99.99**
Endosulfan	6.5-7.5	-	2	1.6	20
Endrin	6.5-7.5	7.5	10	0.01*	99**
Heptachlor	6.5-7.5	240	80	0.1	99.87
Heptachlor	6.5-7.5	17	6.1	0.06	99.02
Toxaphene	6.5-7.5	26	36	1	97.22
Toxaphene	N/A	N/A	49000	100*	99.8**
2,4-D	N/A	-	-	-	-
Sodium Salt	N/A	-	-	-	-
Isopropyl Ester	N/A	-	-	-	-
Butyl Ester	N/A	-	-	-	-
Isooctyl Ester	N/A	-	-	-	-
2,4-D	N/A	N/A	35000	100*	99.7**
2,4-D	N/A	N/A	350000	1000*	99.7**
2,4-D	N/A	N/A	0-250000	1000*	-
2,4-5-T	N/A	7.5	10	0.0*	99**
DDD	N/A	-	-	-	-
DDE	N/A	-	-	-	-
DDT	N/A	7.5	10	0.1*	99**
Methoxychlor	N/A	N/A	2	0.2	90
O-Dichlorobenzene	N/A	N/A	24000	100*	99.6**
P-Dichlorobenzene	N/A	N/A	28000	100*	99.6**
Lindane	N/A	7.5	10	0.1*	99**
Methyl Parathion	N/A	N/A	108000	100*	99.9**
Alachlor	Neutral	-	-	-	-
Propachlor	Neutral	-	-	-	-
Benomyl	N/A	66	42	1*	99**
Dinoseb (DNBP)	6.5-7.5	26	8	.002*	99.98**
DNBP	4.0	300	1200000	5000	99.6
DNOC	7-7.5	16	60	Trace	99**
Bromacil	Neutral	-	-	-	-
Diuron	Neutral	-	-	-	-
Atrazine	N/A	N/A	45000	10*	99.9**

N/A = Not Available   * = Less Than
** = Greater Than

TABLE VII-5
Page 2 of 2 Pages
Continued

	mg/PESTICIDE / mg CARBON AT FINAL CONCENTRATION(PPB)	WATER SOURCE	REFERENCE
Aldrin	3% @ 48	River	Wilder, 1976
Chlorodane	N/A	N/A	Wilder, 1976
Chlorodane	N/A	N/A	Wilder, 1976
Kepone	N/A	River	Wilder, 1976
Dieldrin	1.5% @ 19	River	Wilder, 1976
Dieldrin	1.5% @ 19	River	Wilder, 1976
Dieldrin	1.5% @ 19	River	Wilder, 1976
Endosulfan	N/A	Potable	Eichelberger & Lichtenberg, 1971
Endrin	N/A	River	Robeck, et al, 1965
Heptachlor	N/A	River	Wilder, 1976
Heptachlor	N/A	River	Wilder, 1976
Toxaphene	10% @ 300	River	Wilder, 1976
Toxaphene	N/A	Industrial	E.M. Froelich, 1977
2,4-D	3.2% @ 100	N/A	Aly & Faust, 1965
Sodium Salt	6.6% @ 100	N/A	Aly & Faust, 1965
Isopropyl Ester	6% @ 100	N/A	Aly & Faust, 1965
Butyl Ester	5.5% @ 100	N/A	Aly & Faust, 1965
Iscoctyl Ester	1.7% @ 100	N/A	Aly & Faust, 1965
2,4-D	N/A	Industrial	E.M. Froelich, 1977
2,4-D	N/A	Industrial	E.M. Froelich, 1977
2,4-D	N/A	Industrial	E.M. Froelich, 1977
2,4,5-T	N/A	River	Robeck, et al, 1965
DDD	18% @ 56	N/A	
DDE	1.1% @ 41	N/A	Bernadine & Froelich, 1975
DDE	0.9% @ 38	N/A	Bernadine & Froelich, 1975
DDT	N/A	River	Robeck, et al, 1965
Methoxychlor	N/A	N/A	Eichelberger & Lichtenberg, 1971
O-Dichlorobenzene	N/A	Industrial	E.M. Froelich, 1977
P-Dichlorobenzene	N/A	Industrial	E.M. Froelich, 1977
Lindane	N/A	River	Robeck, et al, 1965
Methyl Parathion	N/A	Industrial	E.M. Froelich, 1977
Alachlor	19% @ 5000*	Distilled	ESE, 1977
Propachlor	18% @ 5000*	Distilled	ESE, 1977
Benomyl	N/A	N/A	Plant 48
Dinoseb (DNBP)	N/A	N/A	Wilder, 1976
DNBP	12.3% @ 4500	Industrial	Enviro Labs, 1975
DNOC	N/A	N/A	Lamborn & Sharp, 1960
Bromacil	20% @ 2000*	Distilled	ESE, 1977
Diuron	8% @ 2000*	Distilled	ESE, 1977
Atrazine	N/A	Industrial	E.M. Froelich, 1976

* Expressed as TOC concentration

The primary design parameter to be considered in hydrolysis is the half-life of the original molecule, which is the time required to react 50 percent of the original compound. The half-life is generally a function of (a) the molecule being hydrolyzed and (b) the temperature and pH of the reaction. This is illustrated in Figure VII-1 which shows the half-life of malathion as a function of pH and temperature. The figure shows that increases in temperature and extremes of pH have significant effect on the half-life.

The effect of molecular structure on the half-life can also be quite striking, as for demeton-O and demeton-S. The molecular structures of these two molecules are presented in Figure VII-2. The principal difference in their structures is the location of the phosphorus double bond. In demeton-O, phosphorus and sulfur are joined by a double bond whereas in demeton-S, phosphorus and oxygen are connected by a double bond. The half-lives for these two compounds at 20°C and pH 13 are 75 minutes for Demeton-O and 0.85 minutes for demeton-S (Melnikov, 1971). This is a difference of nearly two orders of magnitude.

The half-life of a compound can be determined for first and second order reactions as follows. For a first order reaction, the rate ($K\underline{1}$) is dependent only on the concentration (mg/l) of the pesticide chemical.

$$A \overset{K\underline{1}}{\underset{\leftarrow}{\longrightarrow}} B$$

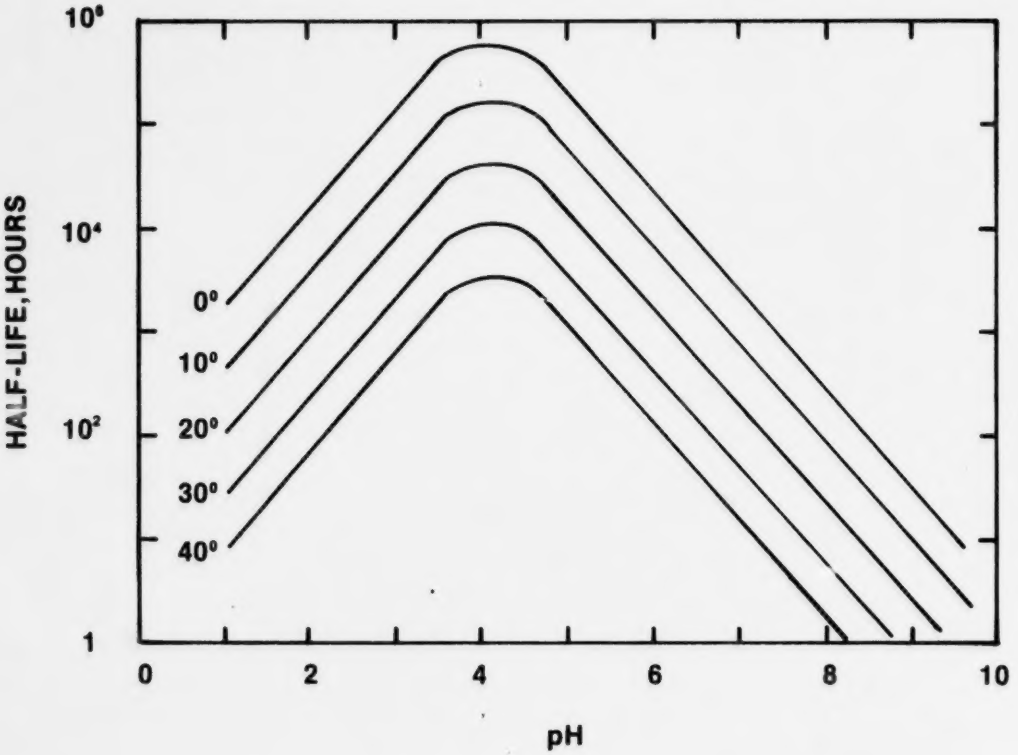
The half-life, t(1/2), is determined by the equation:

$$t(1/2) = \frac{1}{K\underline{1}} \ln 2 = \frac{0.693}{K\underline{1}}$$

As this equation shows for true first-order kinetics, the half-life is independent of the concentration of the pesticide chemical.

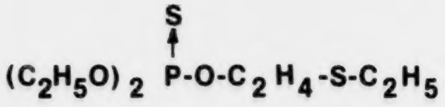
As a general rule, hydrolysis follows second-order kinetics, which depend on the concentration of both the pesticide chemical and hydrogen ion (or hydroxyl ion). However, if the concentration of hydrogen or hydroxyl ions is essentially constant, the above equation is a good approximation.

The reaction constants of hydrolysis for certain classes of pesticide chemicals, specifically carbamates, phosphorothioates,



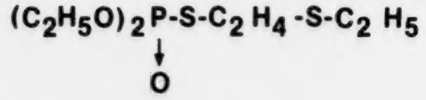
EFFECT OF pH AND TEMPERATURE ON MALATHION DEGRADATION

FIGURE VII-1



$(C_2H_5O)_2\overset{S}{\overset{\uparrow}{P}}\text{-}O\text{-}C_2H_4\text{-}S\text{-}C_2H_5$

DEMETON-O



$(C_2H_5O)_2\underset{O}{\underset{\downarrow}{P}}\text{-}S\text{-}C_2H_4\text{-}S\text{-}C_2H_5$

DEMETON-S

MOLECULAR STRUCTURES
DEMETON-O AND DEMETON-S

FIGURE VII-2

and phosphates, can be calculated from the Bronsted free energy equation.[1]

$$\log K\underline{2} = A\log K\underline{a} + B$$

Where = $K\underline{2}$ = second order reaction rate constant, $\text{mole}^{-1}\ \text{sec}^{-1}$

$K\underline{a}$ = ionization constant for the alcohol formed by hydrolysis

A = slope of the equation

1. Wolf, Zepp, and Paris, "Use of Structure Reactivity Relationships to Estimate Hydrolytic Persistance of Carbamate Pesticides", U.S. EPA; Presented at American Chemicals Society Meeting, New Orleans, 1977.

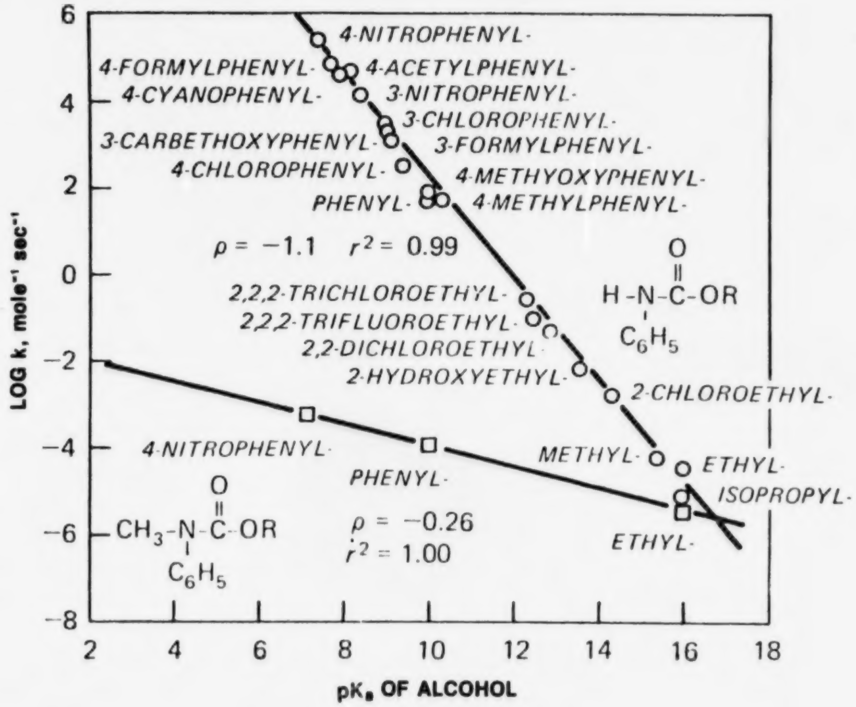
The pKa is the negative logarithm of the Ka. A plot of the log of the reaction rate constant versus the pKa of the alcohol will be a straight line with negative slope A. Figures VII-3 and VII-4 show this relation for four different classes of carbamates. The value of these relationships lies in the fact that the ionization constants for many alcohols are known, whereas the reaction constants for the corresponding carbamates are not.

The reader will notice that a family of lines is shown in these two figures, each line corresponding to a homologous series. For example, the line for N-methyl homologes [$(HNCH_3]COOR)$ is different from that of N,N-dimethyl homologes [$(CH_3)_2]NCOOR$ where R denotes different alkyl and aryl groups. Therefore, for any homologous series, one need only know the reaction constants and corresponding $pK\underline{a}$'s for two compounds and the $pK\underline{a}$ for a third compound to predict the reaction constant for the third compound. As with any experimental work, however, the more data points obtained results in a more accurate prediction.

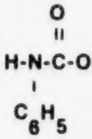
Full-Scale Hydrolysis Treatment Data. Full scale hydrolysis systems are operating at Plants 21, 27, 28, 32 and 34. Data obtained during this study for these plants are presented in Table VII-6.

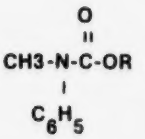
At Plant 21 diazinon is hydrolyzed to 0.049 mg/l. The unit is maintained at a pH less than 1 by the addition of HCl. The basin accomodates 8 to 15 days of flow.

At Plant 27 approximately 70,000 gal/day of waste water from the methyl parathion process are hydrolyzed. The pH is maintained at greater than 11 until the pesticide level is less than 1 mg/l.



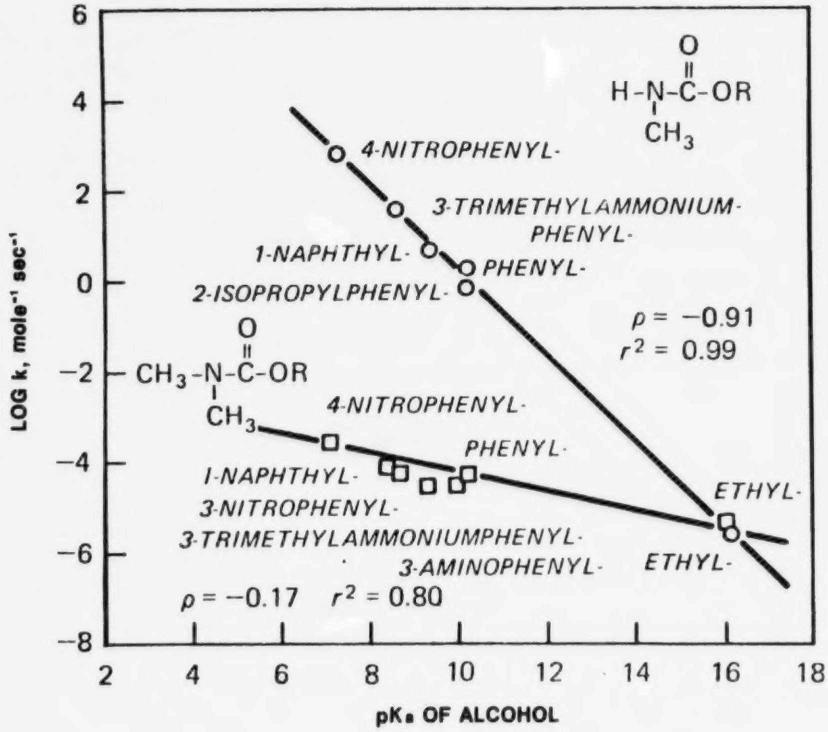
★ AFTER A. WILLIAMS, J. CHEM. SOC. PERKINS II, 1244 (1973)


$\mathrm{H\text{-}\underset{\underset{C_6H_5}{|}}{N}\text{-}\overset{\overset{O}{\|}}{C}\text{-}OR}$: N-PHENYL CARBAMATES

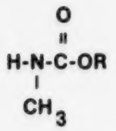

$\mathrm{CH3\text{-}\underset{\underset{C_6H_5}{|}}{N}\text{-}\overset{\overset{O}{\|}}{C}\text{-}OR}$: N-METHYL-N-PHENYL CARBAMATES

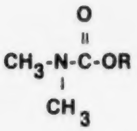
BRONSTEAD PLOT OF THE SECOND-ORDER ALKALINE HYDROLYSIS RATE CONSTANTS OF N-PHENYL CARBAMATES VERSUS pKa OF THE RESULTING ALCOHOL 25°C

FIGURE VII-3



★ AFTER WOLF, et al, PRESENTED AT THE AMER. CHEM. SOC. MEETING IN NEW ORLEANS, 1977.


$H\text{-}N(CH_3)\text{-}C(=O)\text{-}OR$: N-METHYL CARBAMATES


$CH_3\text{-}N(CH_3)\text{-}C(=O)\text{-}OR$: N,N-DIMETHYL CARBAMATES

BRONSTEAD PLOT OF THE SECOND-ORDER ALKALINE HYDROLYSIS RATE CONSTANT OF THE N-ALKYL CARBAMATES VERSUS pKa OF THE RESULTING ALCOHOL 25°C.

FIGURE VII-4

TABLE VII-6
FULL-SCALE HYDROLYSIS DATA

		PESTICIDE					
PLANT	PRODUCT(S)	INFL. mg/l	EFFL. mg/l	PERCENT REDUCTION	pH	DETENTION TIME HOURS	TEMPERATURE *F
21	Diazinon	57.0	0.049	99.9	*1.0	264	Ambient
27	Methyl Parathion	N/A	*1.0	N/A	**11	N/A	Elevated
28	Methyl Parathion & Ethyl Parathion	6.91	0.014	99.8	*10	*120	Ambient
32	Disulfoton	14.8	0.97	93.4	**12	1	144-160
34	Nemagon	N/A	*0.5	-	**12	12	110
	Stirofos	N/A	*0.01	-	**12	12	110
	Dichlorfos	N/A	*0.01	-	**12	12	110
	Naled	N/A	*0.1	-	**12	12	110
	Phosdrin	N/A	*0.1	-	**12	12	110
	Aldicarb	N/A	*0.01	-	**12	12	110

* Less Than
** Greater Than
N/A Not Available

This waste is combined with about 1.37 MGD of other plant waste before discharge to navigable waters.

At Plant 28 parathion is hydrolyzed by first adding caustic in two 120,000 gallon holding tanks and then aerating the basins for 3 to 5 days. Effluent pesticide concentrations are frequently less than 0.01 mg/l.

Representatives of Plant 32 have stated that in-plant hydrolysis of pesticide chemicals is provided. Operating data for disulfoton have been submitted which show effluent levels of less than 0.1 mg/l. The disulfoton waste stream is designed to maintain a pH greater than 12 at 144 to 150 degrees F for one hour.

At Plant 34 more than 150,000 gal/day of waste water is treated in a hydrolysis unit (12 hour detention time). Steam is added to maintain the basin temperature at 110 degrees F, and the pH is kept above 12. Pesticide chemicals in the effluent are generally decomposed below the detection limit.

At Plant 148 20,000 gal/day of ethoprophos and 15,000 gal/day of mephosfolan waste waters are treated via caustic, acid, and chlorine treatment prior to complete evaporation. No treatment data were supplied on their system.

Hydrolysis Literature Data. All known available information relating to the hydrolysis of organic pesticide chemicals has been collected. These data are presented in Tables VII-7 and VII-8.

Data are presented in Table VII-7 for ten phosphates and phosphonates, including the five compounds manufactured by direct dischargers: dichlorvos, mevinphos, naled, stirofos, and trichlorfon. At a moderately elevated pH and temperature (pH = 9.0 @ 38°C), hydrolysis is effective for all five of these compounds, and a majority of the others in this group. The Bronsted free energy relationships for phosphonates, shown in Figures VII-5 and VII-6, as developed by Wolfe (1977), indicate that pesticide chemicals of this type are readily hydrolyzed in alkaline media. For example, in Figure VII-5, at larger values of pKa for dimethoxy phosphate the corresponding second-order rate contact is approximately 10^{-4}mole^{-1}sec^{-1}. This value corresponds to a half-life of 192.5 hours at pH 12 and 25°C. At higher temperatures and lower pKa, the half-lives would be shorter.

TABLE VII-7

HYDROLYSIS LITERATURE DATA
ORGANO-PHOSPHORUS PESTICIDES

PESTICIDE	CHEMICAL TYPE	TEMP. °C	pH	HALF-LIFE MINUTES	REFERENCE
Chlorfenvinphos	Phosphate	70	6.0	5,580	Faust & Gomma, 1972
Crotoxyphos	Phosphate	38	1.0	5,220	Melnikov, 1971
		38	9.0	2,100	Melnikov, 1971
Dichlorvos	Phosphate	37.5	6.0	2,100	Metcalf, et al., 1959
		37.5	7.0	462	Metcalf, et al., 1959
		37.5	8.0	301	Metcalf, et al., 1959
		38	1.1	3,600	Plant 34
		38	9.1	270	Plant 34
		70	7.0	27	Muhlmann & Schrader, 1968
Dicrotophos	Phosphate	38	1.1	144,000	EPA-670/2-75-057
		38	9.1	72,000	EPA-670/2-75-057
Mevinphos	Phosphate	23	7.0	43,200	Plant 34
		23	10.0	480	Plant 34
		23	11.0	84	Plant 34
		43	12.5	6	Plant 34
Naled	Phosphate	38	1.1	3,600	Plant 34
		38	9.1	60	Plant 34
Phosphamidon	Phosphate	23	7.0	19,872	EPA-670/2-75-057
		23	10.0	3,168	EPA-670/2-75-057
Stirophos	Phosphate	27	11.6	110	Plant 34
		50	11.6	24	Plant 34
		50	10.5	4,800	EPA-670/2-75-057

TABLE VII-7
Continued
Page 2 of 4 Pages

PESTICIDE	CHEMICAL TYPE	TEMP. °C	pH	HALF-LIFE MINUTES	REFERENCE
Tepp	Phosphate	25	7.0	408	EPA-670/2-75-057
		38	7.0	198	EPA-670/2-75-057
Trichlorofon	Phosphonate	37.5	6.0	5,340	Metcalf, et al., 1959
		37.5	7.0	386	Metcalf, et al., 1959
		37.5	8.0	63	Metcalf, et al., 1959
		70.0	6.0	180	Muhlmann & Schrader, 1957
		70.0	7.0	42	Muhlmann & Schrader, 1957
		70.0	8.0	36	Muhlmann & Schrader, 1957
		70.0	9.0	6	Muhlmann & Schrader, 1957
Azinphos Methyl	Phosphorodithioate	20	(1-5)	345,600	Muhlmann & Schrader, 1957
		70	6.0	450	Muhlmann & Schrader, 1957
		70	7.0	288	Muhlmann & Schrader, 1957
		70	8.0	144	Muhlmann & Schrader, 1957
		70	9.0	36	Muhlmann & Schrader, 1957
Bromophos	Phosphorothioate	22	13.0	210	Melnikov, 1971
Carbophenthion	Phosphorodithioate	20	13.1	180	Konrad & Chesters, 1969
Chlorpyrifos	Phosphorothioate	20	6.0	2,800,000	EPA-670/2-75-057
		20	9.96	10,368	EPA-670/2-75-057
Coumaphos	Phosphorothioate	100	14.0	16	Kane, et al., 1960
Demeton-O	Phosphorothioate	20	13.0	75	Melnikov, 1971
		37	7.9	318	Crosby, 1969

TABLE VII-7
Continued
Page 3 of 4 Pages

PESTICIDE	CHEMICAL TYPE	TEMP. °C	pH	HALF-LIFE MINUTES	REFERENCE
Demeton-S	Phosphorothioate	20	13.0	0.85	Melnikov, 1971
		20	(1-5)	297,000	Muhlmann & Schrader, 1957
		70	(1-5)	706	Muhlmann & Schrader, 1957
		70	6.0	570	Muhlmann & Schrader, 1957
		70	9.0	252	Muhlmann & Schrader, 1957
Diazinon	Phosphorothioate	20	3.1	706	Gomma, et al., 1969
		20	10.4	8,690	Gomma, et al., 1969
		40	3.1	176	Gomma, et al., 1969
		60	3.1	47	Gomma, et al., 1969
Dimethoate	Phosphorodithioate	70	2.0	1,260	Melnikov, 1971
		70	9.0	48	Melnikov, 1971
Disulfoton	Phosphorodithioate	70	5.0	3,600	Melnikov, 1971
		70	8.0	1,290	Muhlmann & Schrader, 1957
		70	9.0	432	Muhlmann & Schrader, 1957
EPN	Phosphorothioate	37	13.0	0.5	Metcalf, 1959
Ethion	Phosphorodithioate	20	7.0	7,200	Cowart, et al., 1971
Fenthion	Phosphorodithioate	80	Acidic	2,160	Melnikov, 1971
		80	Alkaline	95	Melnikov, 1971
Fenitrothion	Phosphorothioate	30	12.0	272	EPA-670/2-75-057
		30	13.0	12	EPA-670/2-75-057

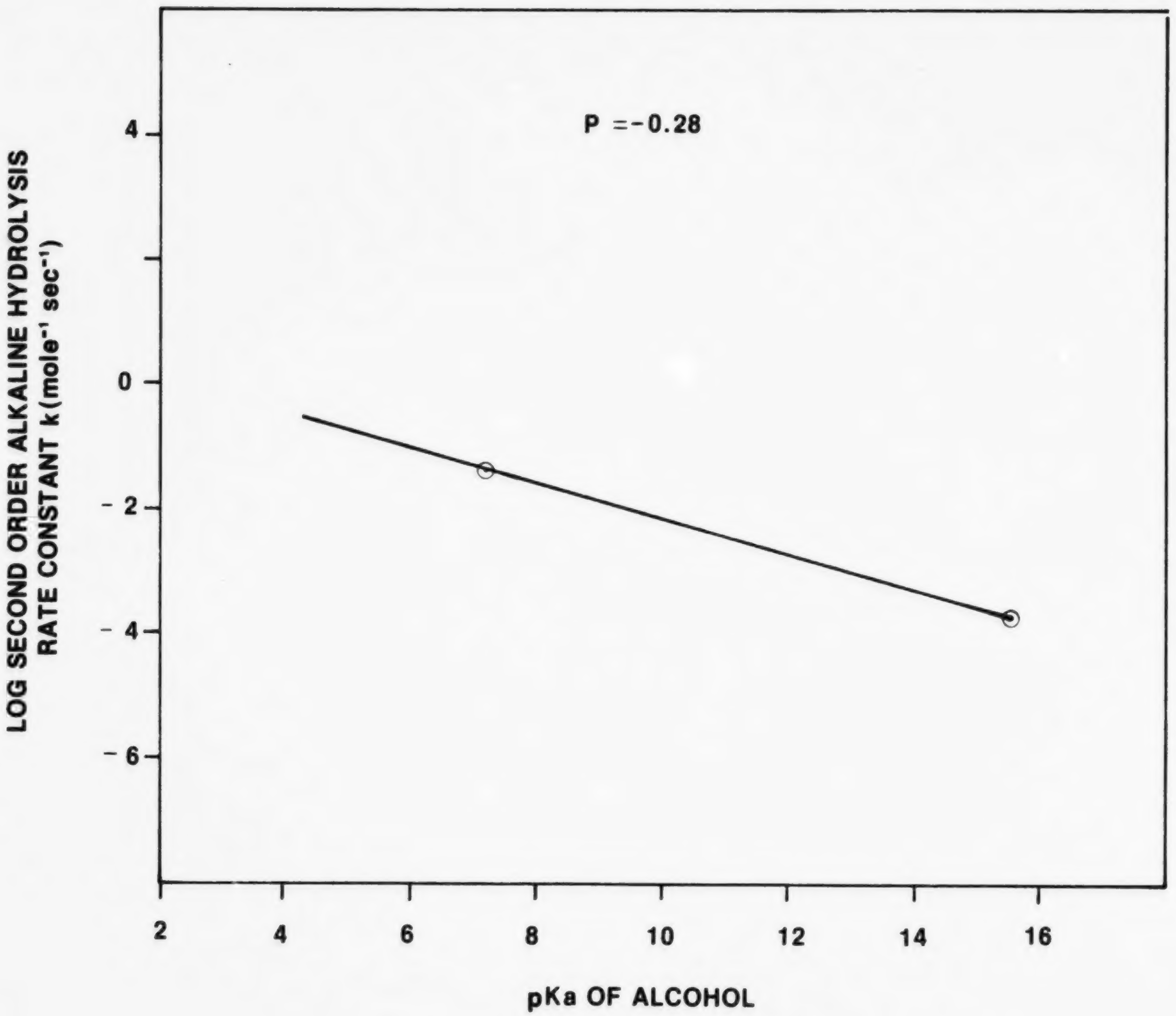
TABLE VII-7
Continued
Page 4 of 4 Pages

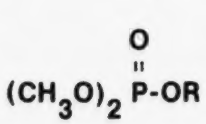
PESTICIDE	CHEMICAL TYPE	TEMP. °C	pH	HALF-LIFE MINUTES	REFERENCE
Malathion	Phosphorodithioate	--	9.0	720	Melnikov, 1971
		--	12.0	10	Melnikov, 1971
		20	6.5	12,960	Cowart, et al., 1971
Parathion Ethyl	Phosphorothioate	10	9.0	76,900	Gomma & Faust, 1971
		20	7.4	156,000	Gomma & Faust, 1971
		20	9.0	31,400	Gomma & Faust, 1971
		20	10.4	1,992	Gomma & Faust, 1971
		40	3.1	48,480	Gomma & Faust, 1971
		40	9.0	7,620	Gomma & Faust, 1971
		60	3.1	10,860	Gomma & Faust, 1971
		60	9.0	1,572	Gomma & Faust, 1971
		70	(1-5)	2,376	Cowart, et al., 1971
		70	1.0	1,200	Melnikov, 1971
		70	9.0	162	Melnikov, 1971
Parathion Methyl	Phosphorothioate	20	(1-5)	252,000	Melnikov, 1971
		30	12.0	210	Melnikov, 1971
		30	13.0	5	Melnikov, 1971
		70	(1-5)	660	Melnikov, 1971
Phorate	Phosphorodithioate	20	(1-5)	10,368	Muhlmann & Schrader, 1957
		30	(1-5)	2,304	Muhlmann & Schrader, 1957
		40	(1-5)	576	Muhlmann & Schrader, 1957
		70	8.0	120	EPA-670/2-75-057
Phosmet	Phosphorodithioate	25	9.3	240	EPA-670/2-75-057
		20	4.5	21,600	Melnikov, 1971
		20	7.0	720	Melnikov, 1971
Ronnel	Phosphorothioate	20	7.0	4,320	Cowart, et al., 1971

TABLE VII-8

HYDROLYSIS LITERATURE DATA
ORGANO-NITROGEN PESTICIDES

PESTICIDES	CHEMICAL TYPE	TEMP °C	pH	HALF-LIFE MINUTES	REFERENCE
Carbaryl	Carbamate	25	8.0	1,872	Wolfe, et al., 1976
		25	10.0	192	Wolfe, et al., 1976
		27	7.0	18,720	Wolfe, et al., 1976
		27	9.0	20	Waushore & Hague
Carbofuran	Carbamate	25	7.1	39,200	Plant 50
		25	8.1	4,800	Plant 50
		25	9.1	342	Plant 50
		37.5	9.5	70	Metcalf, et al., 1968
Propoxur	Carbamate	20	8.0	23,040	Aly & El-Dib, 1971
		20	9.0	2,304	Aly & El-Dib, 1971
		20	10.0	252	Aly & El-Dib, 1971
Captan	Heterocyclic with nitrogen in ring	28	1.97	645	Wolfe, et al., 1976
		28	7.0	155	Wolfe, et al., 1976
Aldicarb	Amide	43	12.0	88	Plant 34
		80	7.0	205	Plant 34
Propham	Carbamate	--	11.0	1,500,000	Wolfe, et al., 1977
		--	13.0	15,000	Wolfe, et al., 1977
Chlorpropham	Carbamate	--	11.0	150,000	Wolfe, et al., 1977
		--	13.0	1,500	Wolfe, et al., 1977
Mexacarbate	Carbamate	12	9.5	2,800	Hosler, 1974

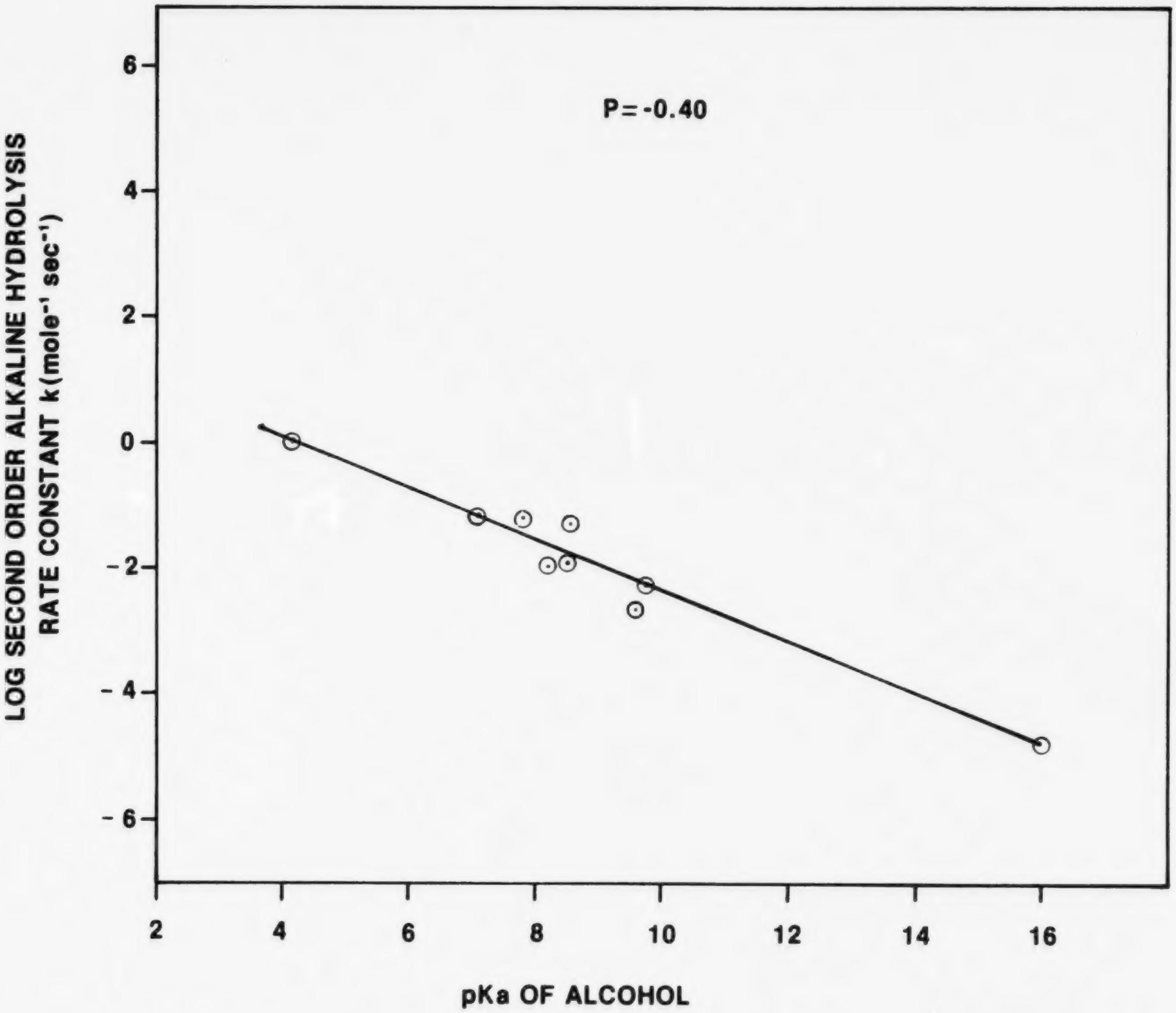


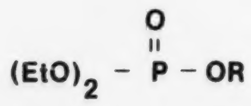


$(CH_3O)_2\overset{O}{\overset{\|}{P}}\text{-OR}$

BRONSTEAD FREE ENERGY RELATIONSHIP
DIMETHOXYPHOSPHATE PESTICIDES

FIGURE VII-5





$$(EtO)_2 - \overset{O}{\overset{\|}{P}} - OR$$

BRONSTEAD FREE ENERGY RELATIONSHIP
DIETHOXYPHOSPHATE PESTICIDES

FIGURE VII-6

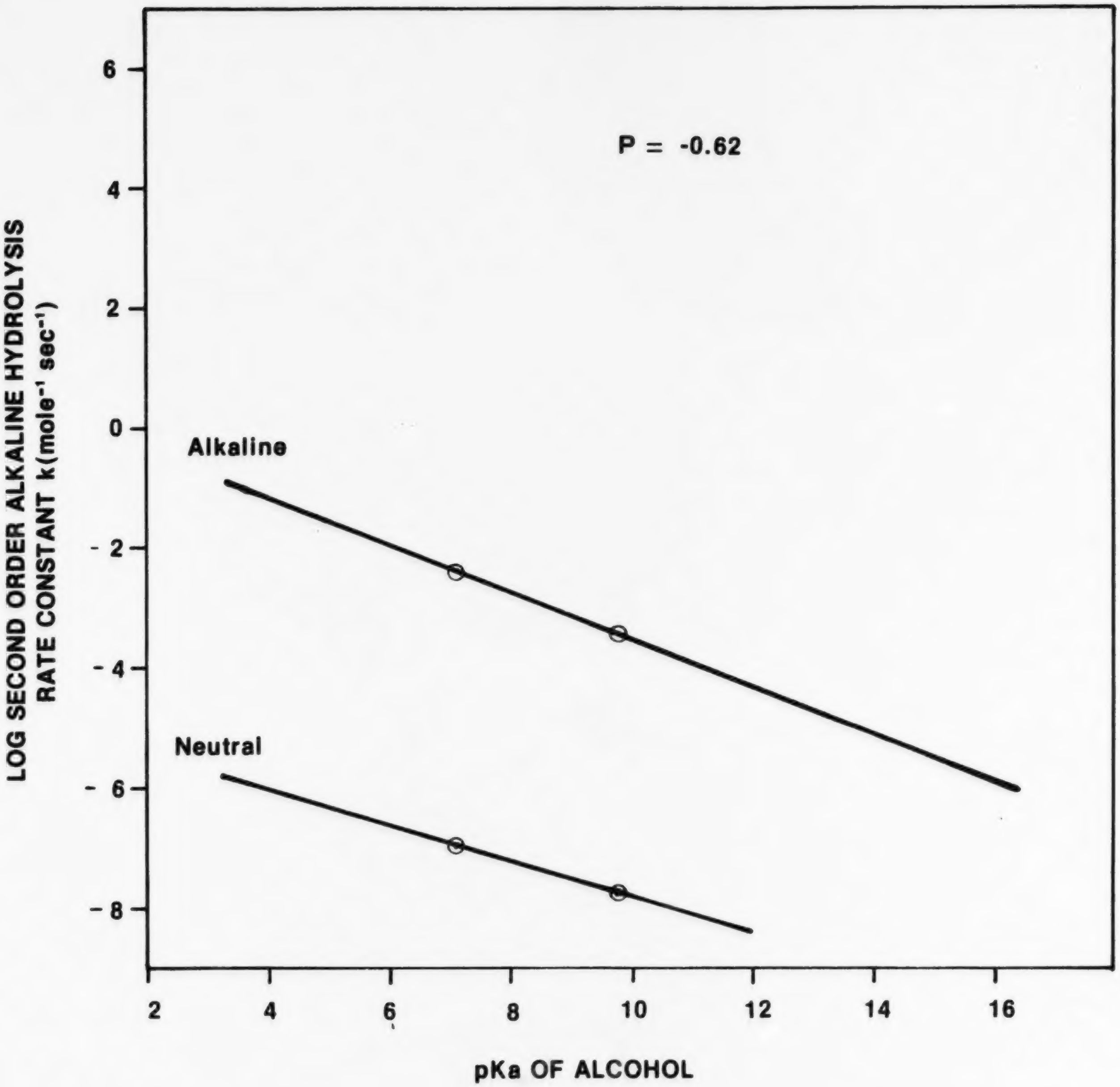
Of the more than 50 phosphorothioates and phosphorodithioates, 17 are manufactured by direct dischargers. These are: aspon, azinphos-methyl, chlorpyrifos, coumaphos, demeton-O, demeton-S, diazinon, disulfoton, ethion, fenthion, fensulfothion, malathion, oxydemeton methyl, parathion ethyl, parathion methyl, phorate, and ronnel. Table VII-7 presents data that indicate 13 of these are amenable to hydrolysis. The structure of the molecules is similiar and hydrolysis rates can be predicted. Of the remaining four, chlorpyrifos is currently deep well injected at Plant 22, aspon is deep well injected at Plant 29, and fensulfothion and oxydemton methyl are being hydrolyzed at Plant 32, although no data are available.

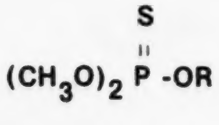
Wolfe (1977) by refering to Figures VII-7 and VII-8 states that the following are also amenable to alkaline hydrolysis: bromophos ethyl, chlormephos, chlorthiophos, cythioate, DEF, dichlorofenthion, famphur, fensulfothion, IBP, mecarbam, menazon, methidathion, monocrotophos, morphothion, oxydemeton methyl, pirimiphos ethyl, piriphos methyl, pyrazophos, quninalphos, temephos, thiometon, and traizophos.

Three phosphorus-nitrogen pesticides are manufactured by direct dischargers. Crufomate is being deep-well injected at Plant 22. Methamidophos is being hydrolyzed at Plant 32. Glyphosate is undergoing biological treatment at Plant 33. However, the degree of pesticide chemical removal is unknown at this time.

Four amide and amide-type compounds are manufactured by direct dischargers. As shown in Table VII-7, aldicarb hydrolyzes readily in an alkaline environment. Hydrolysis testing for propachlor and butachlor have been conducted at Plant 41. It has been reported that they degrade into their corresponding anilines which are known carcinogens. For these reasons activated carbon technology was studied and has been shown to be effective (see Table VII-5). This technology is currently being designed at this plant. Alachlor, as reported by personnel at Plant 41, decomposes under acid conditions. The Bronsted free energy diagrams (Figures VII-3 and VII-4) show that N-phenyl and N-methyl carbamates hydrolyze very quickly at 25°C as is evidenced from the fairly large value of the second-order rate constants. They also show that N-methyl-N-phenyl and N,N-dimethyl carbamates will also hydrolyze, although the reaction rates are somewhat slower.

Three carbamates are manufactured by direct dischargers-benomyl carbofuran, and carbaryl. Benomyl undergoes biological treatment at Plant 48; however, pesticide reductions have not been documented. Carbofuran is amenable to both hydrolysis and activated carbon treatment and is presently treated by the latter

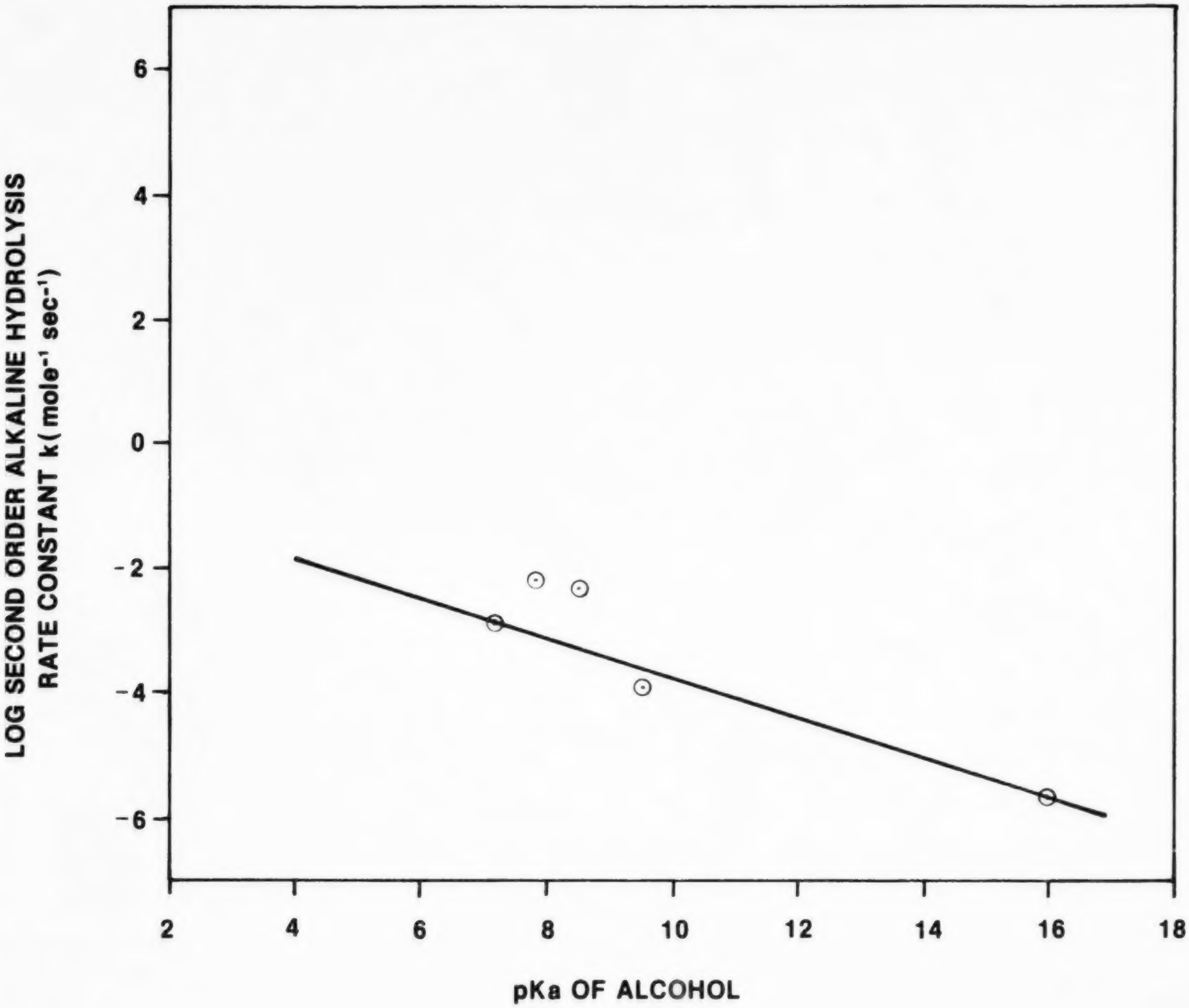


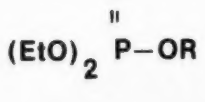


$(CH_3O)_2\overset{S}{\overset{\|}{P}}-OR$

BRONSTEAD FREE ENERGY RELATIONSHIP
DIMETHOXYPHOSPHOROTHIOATE PESTICIDES

FIGURE VII-7





$(EtO)_2\overset{S}{\overset{\|}{P}}-OR$

BRONSTEAD FREE ENERGY RELATIONSHIP
DIETHOXYPHOSPOROTHIOATE PESTICIDES

FIGURE VII-8

technology at Plant 50. As shown in Table VII-8, carbaryl hydrolyzes relatively easily. In addition to literature data presented in Table VII-8, Wolfe (1977) indicates that aminocarb, asulum, benomyl, carbetamide, desmedipham, formetanate hydrochloride, karbutilate, meobal, metalkamate, methiocarb, pirimicarb and promecarb are also amenable to hydrolysis treatment techniques.

No hydrolysis information was discovered relative to the two compounds in the group identifiable as cyanates. Thanite, the only compound manufactured by a direct discharger, can be removed using activated carbon.

No hydrolysis information was located for heterocyclic compounds with nitrogen and oxygen in the ring; nor are any manufactured by direct dischargers.

Literature data for heterocyclic compounds with nitrogen in the ring is limited to captan, which has been shown to hydrolyze readily at neutral pH and room temperature. Two additional compounds are manufactured by direct dischargers. Piperalin is treated by both biological and incineration systems at Plant 39. Maleic hydrazide is treated by a biological system at Plant 146. Pesticide removal is not monitored by either plant.

The four nitro and nitro-amine pesticides manufactured by direct dischargers are benfluralin, isopropalin, trifluralin, and dinoseb. Due to the potential for hydrolysis to produce dinitrophenols, a more toxic compound, carbon should be considered as the primary technology. All of the above pesticide chemicals are amenable to activated carbon treatment.

Two thiocarbamates are manufactured by direct dischargers. Amobam is treated by an aerated lagoon system at Plant 149. However, no monitoring has been conducted. Triallate waste water was inhibitory to the biological system at Plant 33; the waste is currently being deep-well injected while pretreatment studies are being conducted.

Chloro and dichloroanilines, suspected carcinogens, are potential hydrolysis byproducts from the following ureas: monolinuron, linuron, monuran, monuron-TCA, neburon, siduron, diuron, fluometuron, and metoxuron. Due to the success of isotherm tests for diuron and bromacil, ESE (1977), carbon technology should be considered as the primary technology for both ureas and uracils.

Another nitrogen pesticide manufactured by direct dischargers is bentazon. Bentazon will be treated in a full-scale oxidation system at Plant 49. The plant is scheduled to use hydrogen peroxide as the oxidizing agent. Pilot data are presented later in this section.

Additional Pesticide Removal Processes

Although activated carbon adsorption and hydrolysis are the most common forms of pesticide removal, other alternatives in practice or under design in the industry are incineration, resin adsorption, chemical oxidation, clay adsorption, powdered carbon, and multiple-effect evaporation.

From the results of incineration studies, Carnes (1976) reached the following conclusions: 1. most organic pesticide chemicals can be destroyed (greater than 99.9 percent removal of the active ingredient) by this method; 2. each pesticide incinerated has a definite temperature range at which the greatest removal of the active ingredient is effected; 3. the most important incineration factors are the temperature and the dwell time in the combustion chamber; 4. conventional waste incinerators are potentially adequate facilities for pesticide chemicals incineration; 5. nitrogen based pesticide chemicals can generate cyanide gas if the incineration temperatures and percent excess air are not adequate; 6. incinerators burning pesticide chemicals will require emission control devices; 7. residues from the incineration of pesticides formulations generally contain low levels of pesticide chemicals; and 8. odor can be a problem, especially in the incineration of organo-sulfur compounds.

One manufacturer utilizes incineration where wastes are malodorous, not easily biodegraded, inhibitory to biological microorganisms, and where inorganic salt content is high. BOD, COD, and TOC reductions exceed 95 percent. TKN (total kjeldahl nitrogen) reductions are much less due to ammonia in the scrubbing liquid. The system is acknowledged to be costly and energy intensive, but the plant has determined it to be justified in this situation.

Resin adsorption is being installed at Plant 18 for the treatment of methyl parathion. At Plant 23 a pilot resin adsorption system has been tested in conjunction with a sand-filtered, copper-catalyzed, iron powder, reduction bed filter. The combined system has removed up to 99.9 percent of the pesticide chemicals.

At Plant 49 a chemical oxidation system has been designed using hydrogen peroxide (H_2O_2). A pesticide reduction of 98.8 percent is predicted using a 1.0 percent by volume solution H_2O_2. Steam stripping with solvent recycle is also part of the pretreatment prior to secondary treatment of the combined pesticide and non-pesticide waste waters.

At Plant 3 a series of settling ponds are operated; more than 95 percent of the pesticide chemical is removed by adsorption onto clay.

At Plant 36 a powdered carbon adsorption system has been designed; it includes a wet air-oxidation regeneration of the spent powdered carbon. Greater than 99 percent pesticide chemical removal is expected in conjunction with 90 percent TOC removal.

An evaporation-crystalization system has been installed at Plant 50 to eliminate the discharge of metallo-organic pesticides. Evaporator condensate is sent to the municipal treatment system.

IN-PLANT CONTROL TECHNOLOGY

In conjunction with pesticide chemical removal systems, steps should be be taken to minimize waste water strength and/or volume. The following discussion addresses techniques which have general application.

Waste segregation can be an important and fundamental step in waste reduction. The following factors generally form the primary basis for waste segregation:

1. Wastes with high organic loadings may be economically treated or disposed of separately from the main process waste water. As discussed in more detail later, segregation for pesticide chemicals removal and specific parameter control can be both effective and economical.

2. Highly acidic and caustic waste waters can usually be more effectively adjusted for pH prior to being mixed with other process waste waters. If both acidic and caustic streams are being generated, combining these streams can reduce chemical requirements.

3. Process waste waters with high levels of settleable solids can be clarified separately.

4. Separate equalization for streams of highly variable characteristics can be effective and improve overall treatment efficiency. This highly effective technique is common practice in the industry.

In some cases, waste water generation can be substantially reduced by the substitution of an organic solvent for water in the synthesis and separation steps of the production process with subsequent solvent recovery.

Waste water generation can be reduced by general housekeeping improvements such as the substitution of dry cleanup methods for water wash downs of equipment and floors. This is especially applicable for situations where liquid or solid materials have been spilled.

Steam jet ejectors and barometric condensers can be replaced in some cases by vacuum pumps and surface condenser systems. Barometric condenser systems can be a major source of contamination and can cause a particularly difficult problem by producing a high volume, dilute waste stream.

Recycle of waste water is commonly practiced in conjunction with solvent extraction, steam stripping and distillation materials recovery operations. Wash water, rainwater runoff, and scrubber effluent may often be recycled to the process. It is particularly common in the metallo-organic and the formulating and packaging subcategories to recycle all wastes to the process.

Biological Treatment

Since the waste waters generated by the pesticide chemicals industry are for the most part biodegradable, biological treatment is the most applicable technology. Activated sludge and aerobic lagooning are the most common types of biological treatment employed. High-strength industrial waste commonly requires modifications of the activated sludge design that is normally applied to treatment of municipal waste. These modifications include equalization, treatment at essentially a constant rate, a longer detention times, completely mixed basins, and larger constant rate, secondary clarifiers. The complete-mix system is generally preferred over other activated sludge systems because it is less susceptible to shock loads (the completely mixed basin partially smooths out organic load variations), oxygen utilization rate is constant throughout the basin, and lined earthen basins can be used for economy.

A primary disadvantage of any activated sludge system is operational difficulty. Operators should be adequately trained to maintain continuous operation and minimize problems and upsets. Perhaps the most common operating problem is "sludge bulking" in which rising sludge in final clarifiers causes floating matter to be discharged in the plant's effluent. The floating material can considerably increase BOD and suspended solids concentration in the effluent.

Sludge bulking can often result from poor operation allowing inadequate aeration or nutrient levels, improper food to microorganism ratio, or improper sludge age. It is essential that operators maintain frequent (at least daily) testing of the dissolved oxygen levels, suspended solids concentrations, and nutrient concentrations in the effluent, and, of course, the sludge volume index. If upsets still occur even with the best operation and most constant monitoring, it may be necessary to take additional measures such as the addition of filtration, increased equalization, or greater clarification.

Any biological treatment system requires a period of stabilization before optimum efficiency can be expected. This period may range from a few weeks up to a year or more, with the longer period often resulting in part from the time needed for operators (even those with previous experience) to learn the eccentricities of a particular system. During this start-up period, large variations in both BOD and suspended solids concentrations can be expected in the discharge.

The period of initial stabilization of a biological system used for pesticide waste waters can be lengthened by high salt concentrations requiring special efforts in acclimating a microbiological culture. Several plants have demonstrated the achievability of an acclimated culture.

Another problem associated with biological systems is sludge generation. The sludge from an activated sludge system can be expected to have a solids content normally ranging from 1.0 to 2.0 percent and, on a dry weight basis, can be generated at a rate of about 0.5 kg per kg of BOD.

Climatic conditions may also affect biological systems. Decreased biological activity can be normally expected during winter months. In extremely cold climates, added cost may be necessary for the heating of treatment systems.

Table VII-9 presents a summary of available data relating to Subcategory 1.

The treatment at Plant 19 consists of pH adjustment, dechlorination with sodium hydrosulfide, presettling, equalization, clarification, mixed media filtration, activated carbon dechlorination, extended aeration, and final clarification. Table VII-9 presents five months of data soon after start-up of the system.

TABLE VII-9
BIOLOGICALLY TREATED EFFLUENT SUMMARY
ORGANIC PESTICIDES CHEMICALS MANUFACTURERS
SUBCATEGORY I

PLANT	PRODUCT(S)	FLOW			BOD			COD			TSS			PESTICIDES			SOURCE OF DATA
		L/Kkg	Gal/1000 lb	(n)	Kg/Kkg	mg/l	(n)	Kg/Kkg	mg/l	(n)	kg/Kkg	mg/l	(n)	kg/Kkg	Mg/l	(n)	
19+	9,10	64800	7770	(34)	2.53	39.0	(34)	19.4	299	(28)	1.17	18.0	(28)	0.00430	0.0452	(40)	a
21+	3-14	18900	2270	(334)	1.11	58.5	(323)	NM	NM	(0)	1.36	72.1	(329)	N/A	N/A	(0)	b
	3	(a)	(a)	(0)	(a)	(a)	(0)	(a)	(a)	(0)	(a)	(a)	(0)	0.000762	0.0018	(314)	
	4-12	(a)	(a)	(0)	(a)	(a)	(0)	(a)	(a)	(0)	(a)	(a)	(0)	0.269	3.55	(283)	
	13,14	(a)	(a)	(0)	(a)	(a)	(0)	(a)	(a)	(0)	(a)	(a)	(0)	1.27	0.57	(55)	
27+	15	N/A	N/A	(0)	N/A	N/A	(0)	N/A	N/A	(0)	N/A	N/A	(0)	0.00315	0.0129	(36)	c
28	15,16	50000	6000	(15)	0.641	10.8	(65)	7.01	140	(450)	19.1	381	(184)	0.0007	0.0139	(450)	d
32+	17-25	46700	5600	(458)	3.44	73.6	(171)	59.7	1280	(444)	3.20	68.5	(455)	0.372	2.39	(62)	e
		(a)	(a)	(0)	(a)	(a)	(0)	(a)	(a)	(0)	(a)	(a)	(0)	0.008	N.A.	(39)	
41+	26,27,28	23700	2840	(61)	1.00	42.2	(60)	10.2	431	(61)	1.08	45.6	(61)	1.13	35.7	(60)	f
		31100	3730	(209)	2.86	91.9	(118)	23.3	749	(209)	4.12	133	(209)	3.77	91.1	(206)	g
48+	29	7000	840	(E)	0.1	N.A.	(E)	6.4	N.A.	(E)	0.1	N.A.	(E)	0.3	N.A.	(E)	h
	30	N.A.	N.A.	(0)	0.2	N.A.	(E)	6.1	N.A.	(E)	1.1	N.A.	(E)	1.2	N.A.	(E)	i

(n) = number of data points available
NM = not monitored
AI = analytical interference
(E) = plant estimate
N/A = not applicable
N.A. = not available
* = less than

None = no process wastewater discharged to treatment units
+ = discharges to navigable waters
(a) = discrete data for individual products in plants with combined flow is not applicable except for the pesticide parameter

TABLE VII-9

Continued
Page 2 of 2 pages

NOTES:

PRODUCT CODE:

1 = DCPA
2 = Chloronthalonil
3 = Diazinon
4 = Anilazine
5 = Propazine
6 = Simazine
7 = Profluraline
8 = Ametryne
9 = Prometryne
10 = Simetryne
11 = Prometone
12 = Cyanazine
13 = Chloropropylate
14 = Chlorobenzilate
15 = Methyl Parathion
16 = Ethyl Parathion
17 = Fensulfothion
18 = Disulfoton
19 = Fenthion
20 = Azinphosmethyl
21 = Oxydemetonmethyl
22 = Methamidophos
23 = Demeton
24 = Phorate
25 = Trichloronate
26 = Alachlor
27 = Propachlor
28 = Butachlor
29 = Methomyl
30 = Diuron

SOURCE OF DATA CODE:

(a) Daily composites, 1/5/77 through 5/16/77. Ratios developed by using total: final production ratio of 1.46:1, due to chloral waste

(b) Daily composites, 4/75 through 2/76. Ratios developed by utilizing total: final product ration of 4:1, due to intermediate and non-pesticide production

(c) Weekly average of effluent, 1/9/76 and 7/9/77. Combined plant effluent is not applicable due to titanium dioxide and sodium chlorate representing 92 percent of flow

(d) Daily composites, 1/74 through 3/75. TSS 5/77 through 10/77

(e) Daily composite, 10/75 through 12/76. Ratios developed by using total: final product ratio of 3.33:1 due to manufacture of intermediates. Disulfoton data, 1/76 through 9/76, weekly composite.

(f) Daily composite, 4/77 through 5/77

(g) Daily composite, 9/76 through 3/77

(h) Plant estimate, 9/9/77

(i) Plant estimate, 8/31/77

Plant 21, where a variety of pesticide chemicals are manufactured, hydrolyzes specific pesticide chemical streams and biologically treats all pesticide chemicals waste waters. A stripper is used to recover solvent for reuse in the process. During a representative 30-day period in May 1975, diazinon was hydrolyzed 99.9 percent to a level of 0.01 kg/day (0.03 lb/day) prior to biological treatment. The hydrolysis basin is maintained at a pH less than 1 at ambient temperature during 8 to 15 days of detention time. The biological system has been acclimated to a chloride concentration of 20,000 mg/l and is designed for 30,000 mg/l. Table VII-9 presents the monthly mean values from daily sampling for one year of the final effluent. Parameters monitored include BOD, TSS, and diazinon. The treatment system achieves consistent removal of the above parameters.

At Plant 27 methyl parathion waste water is hydrolyzed. Due to high salinity the waste is then diluted with non-pesticide effluents and treated in a biological system including final clarification. Methyl parathion is analyzed at the effluent from the system as part of NPDES requirements.

Acidic process wastes produced at Plant 28 are discharged through a limestone pit increasing the pH from a range of 1 - 2.5 to 4 - 5. The discharge from the limestone pit is combined with alkaline waste and the total stream is passed into two agitated holding tanks which include facilities for caustic addition. Analyses of samples for parathion, paranitrophenol, pH, and COD in the holding tank discharge are used to determine the feed rate to the subsequent aeration basins. The centrifuged sludge from the activated sludge system is disposed of on land; the treated waste water is discharged to a municipal system. The treatment system is reported to remove 95 to 98 percent of the influent COD, and has a discharge concentration of less than 0.02 mg/l of methyl-ethyl parathion. The solvent used in production is distilled off and recycled.

The effluent COD level averaged 6.137 kg/kkg and ranged from 2.225 to 12.252 kg/kkg. Parathion in the effluent averaged less than 0.000647 kg/kkg and ranged from less than 0.00005 to 0.00158 kg/kkg. Suspended solids levels presented in Table VII-9 reflect recent changes in the operation of the treatment system. Increased plant production has resulted in higher hydraulic loading. Mixed liquor suspended solids (MLSS) concentrations of 35,000 mg/l are now being employed. Due to these changes two additional clarifiers have been added to the two existing units.

At Plant 32, which both manufactures and formulates, a biological treatment system (pure oxygen) is employed. Pesticide chemical reduction at each process line is also practiced in advance of the biological system. A pure oxygen system was chosen in preference to an air system because of reduced odor problems. Waste gases are piped to a thermal oxidation system. Segregation, phenol recovery and the use of surface condensers are also practiced.

Due to relatively high salinity (2,000 to 3,000 mg/l chloride) the raw waste water is diluted approximately 150 percent prior to activated sludge treatment. The MLSS concentration is maintained relatively high (6,000 to 8,000 mg/l). The final clarifiers were designed at 250 gpd/square foot. Ammonia stripping is practiced on the non-pesticide streams. A first-phase ammonia stripping facility was planned to be in operation by 1977 and a second by 1978. The final effluent is discharged to a receiving stream while sludge, after thickening and vacuum filtration, is hauled to landfill.

The following percentage removals occur (using kg/kkg); BOD - 82.1%, COD - 32.8% and pesticide 31.1%. As these figures indicate, the short detention, pure oxygen system is not achieving the removals possible with longer detention, complete mix activated sludge systems at plants such as 28 and 41. The indication is that the design and/or operation of the treatment facility is insufficient for the type of waste involved.

The hydrolysis pretreatment is not uniformally applied, as indicated by the level of hydrolysis for disulfoton compared to the average level for the entire plant (0.008 to 0.372 kg/kkg).

Table VII-9 reports pesticide levels for two different pesticide parameters. An average of 0.372 kg/kkg pesticide chemicals was discharged from the treatment system during the period October 1975 through December 1976. Representatives of the plant have stated that each pesticide was hydrolyzed to some degree. The exact operating conditions are not available at this time. The effluent from hydrolysis of disulfoton was monitored for 9 months by the plant. The level of 0.008 kg/kkg represents the level attainable for this specific pesticide under known conditions.

At Plant 34 an aerated lagoon (90 day detention time) with a volume of 6,800 cu m (18 million gal) and 140 kw (190 hp) of aeration is currently under construction. Pilot work at the plant has indicated that the biological system can be properly acclimated to the waste water, which contains chloride concentrations of approximately 30,000 mg/l. Organic reductions in a 50 cu m (13,000 gal) simulated aerated lagoon were 68 percent for TOC and 88 percent for BOD, resulting in an effluent BOD concentration of approximately 8 mg/l.

Plant 39 manufacturers isopropalin and discharges the waste water to a biological treatment system. The plant did not supply treated waste load data for this product.

At Plant 41 a treatment system composed of neutralization, equalization, and activated sludge has recently been started-up. Representatives of the plant have stated that April and May 1977, represent normalized operating conditions. Although no pesticide removal is currently practiced, studies are underway in the areas of pollutant reductions, granular activated carbon, powdered carbon, clay adsorption, resin adsorption, wet air oxidation, and hydrolysis. Table VII-9 presents data from this system. Total effluent levels have been adjusted by a ratio of 1.33:1 due to the contribution of three intermediate chemical waste streams. This ratio was based on raw waste load sampling which indicated that intermediates contributed only 25 percent of the total load to the treatment system.

A treatment system operated at Plant 48 is composed of equalization, activated sludge, and a polishing lagoon. Table VII-9 contains effluent estimates by the plant personnel for two compounds: bromacil and diuron. Since this system handles pesticide and non-pesticide wastes, the effluents represent existing reductions applied to measured raw wasteloads, or in the case of pesticide chemicals, predicted effluents from the application of currently known methods.

Representatives of Plant 49 have submitted predicted effluent data from their pretreatment and activated sludge treatability studies on bentazon, as shown in Table VII-9.

Other Treatment

At Plant 3 the production area has been diked to contain all leaks or spills. Baghouses are used for dust collection and the dust is recycled. Tank cars are dedicated to a specific product and their washing is thereby reduced to once per year. The wash water is recycled. Extensive efforts have been made to improve housekeeping and reduce water usage by equipment modifications and better maintenance. All process water, spillage, and floor washings are treated in a separate tank to separate, recover, and recycle any free toxaphene or toxaphene solution. A similar system is used for rainwater runoff and the solution makeup, packaging, and shipping areas. A special crew is used to clean up spills. If it is necessary to remove a piece of equipment from the diked process area, the equipment is first thoroughly decontaminated. Process waste, neutralized by caustic soda and limestone, is mixed with clarified storm water and further clarified. This effluent is then combined with cooling water prior to final discharge to a stream. Sludge from the drying beds is disposed of in a landfill. This system was designed to remove 90 percent of the toxaphene concentration in the influent (2 mg/l to 0.2 mg/l) to an average level of 0.107 mg/l (0.000943 kg/kkg). According to plant personnel, the system actually achieves greater than 95 percent removal.

Plant 4 waste water discharge from its toxaphene production area has been eliminated by dry-cleaning of spills and the use of solvent instead of water for equipment washing. The cleaning liquor is recovered and used in the process. The production area is completely diked.

Plant 9, which is currently closed, employed no waste water treatment. The plant was meeting its toxaphene discharge limitation of 0.04 lb/day (0.001 kg/kkg) through in-plant control. An official of the plant stated that no discharge is theoretically achievable through the control of all leaks, the recovery of all hydrochloric acid, and the conversion of all fugitive hydrogen chloride and chlorine gases into bleach. However, in ordinary operations some discharge would inevitably be required.

All contaminated and non-reusable process waste water and wet scrubber effluent discharged at Plant 12 is disposed of in a sanitary landfill without pretreatment.

The only discharge from the toxaphene process at Plant 18 is spent caustic which is generated at a rate of about 10 gallons per minute. A company official has stated that independent analyses have detected no toxaphene concentrations in this stream.

At Plant 34, where a variety of pesticide chemicals are manufactured, processing steps have been selected that minimize usage of process water. The process streams are segregated, and the plant provides emergency storage facilities, uses special pump seals to reduce leakage, and recycles cooling water. Hydrolysis is provided to remove the pesticide chemicals, followed by pH adjustment and final holding in a one acre pond prior to discharge to receiving waters.

Non-aqueous streams at Plant 34 are either trucked to off-site contract disposal or sent to a liquid/gas incinerator. As a result, the primary effluent contaminants are inorganic salts that result from the scrubbing of vent and flue gases. Rain and wash waters are combined with scrubber waters and tank farm drainage from several process areas, and the pH is adjusted to 10 with caustic. The combined waste is further combined with other neutralized process wastes in a settler and phase separator, and additional caustic is added before removal of insoluble organics in an API separator. Skimmed oil is incinerated. The separator effluent is further treated with 20 percent caustic and sent to a treatment basin; there it is combined with effluent from a sanitary package plant. Steam is added to bring the temperature to 43°C and the final alkaline hydrolysis step occurs before discharge to the final holding pond. The data in Table VII-10 relate to the effluent. Hydrolysis at elevated temperature and pH during the period November 1975 through March 1976 resulted in no detectable pesticide chemicals in the effluent.

Plant 48 incinerates Lannate and discharges the incinerator scrubber water to a biological treatment system.

Subcategory 2: Metallo-Organic Other Treatment Pesticide Chemical Manufacturers

At Plant 55 all arsonate process waste water is recycled to the process. No process waste waters are discharged. Condenser cooling water and storm water are collected in a series of four evaporation ponds. Sampling reports revealed approximately 1 mg/l arsenic in the ponds.

All process waste water resulting from the manufacture of arsenate herbicides is recycled to the process at Plant 56. Only non-contact cooling water and storm runoff are discharged. Acid waters are truck hauled to recovery operations, and some solids are truck hauled to a landfill.

At Plant 58, mercury wastes are totally recycled into the process.

Complete reuse of all arsonate process waste water was initially reported for Plant 19. It was indicated that the process actually had a negative water balance in that all process and even storm water could be reused. The Agency has since been advised that the initial information was in error and that a process waste water discharge was required. The Agency is presently investigating this report.

Two copper-based pesticide producers, Plants 54 and 57 report no discharge of waste water. Plant 57 disposes of a small volume by contract hauling to landfill.

Subcategory 3: Pesticide Chemical Formulators/Packagers

Formulation and blending operations are generally conducted on a batch basis and the same equipment is used for many products.

TABLE VII-10

HOLDING POND EFFLUENT
PLANT 34

DATE	FLOW		COD		TOC		TSS	
	L/Kkg	Gal/1000 Lb	Kg/Kkg	mg/l	Kg/Kkg	mg/l	Kg/Kkg	mg/l
Nov 75	47500	5700	12.3	259	6.85	144	0.419	8.81
Dec 75	19700	2360	7.16	364	4.59	233	0.172	8.74
Jan 76	17900	2150	6.83	381	4.60	256	0.171	9.53
Feb 76	29900	3580	12.0	402	7.14	239	0.344	11.5
Mar 76	51700	6200	11.6	224	7.23	140	0.507	9.80
Mean	33,400	4000	9.98	299	6.08	182	0.323	9.68

Vessels are cleaned between batches to avoid cross-contamination. Many plants use storage tanks to hold wash liquids in order that they can be used for makeup purposes during the next formulation of the same product. This procedure reduces the total quantity of washwater generated and minimizes product losses. It can be applied in plants where both water and solvent-based products are manufactured. For example, Plant 101 performs all liquid equipment cleaning with solvents, which are collected and used in the next batch formulation.

Housekeeping is particularly important for formulators since virtually all waste water generated is from equipment and floor cleanup. Nearly all formulators use dry floor and spill cleanup techniques and solvent recovery, for example Plants 56-95 and 101.

Evaporation is the predominant disposal technique employed by formulators which generate some waste water. This method was noted at Plants 56 through 95 which are located in the Southeast, Midwest, and Southwest. Spray recirculation is commonly used in those areas in which precipitation rates equal or exceed evaporation rates. Other methods of enhancing evaporation used in the industry include supplemental heat and coverings. The flows from these plants range from a few hundred liters per day to several thousand liters per day. Disposal of waste water to landfills or by contract operators is also employed by formulators, as noted in Table VII-2.

Spray irrigation of treated waste water is practiced at Plant 101. The treatment includes oil skimming, chemical coagulation, vacuum filtration, and aeration. During three to four months of the year, spray irrigation is prohibited by climatic conditions and the effluent from the pretreatment system is discharged to a municipal sewer system. However, it is anticipated (as confirmed by plant personnel) that with additional effort all waste water could be excluded from the municipal sewer.

For this study seventy-five formulation facilities registered under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) were randomly selected. Their operations were reported to be devoted exclusively to formulation and packaging. Forty-four were found that currently formulated and all had no discharge of waste water to navigable waters. In addition, 23 combined manufacturing and formulating facilities which do discharge to navigable waters report no significant waste water generation from formulation or packaging activities. Any facility generating waste water from a formulation or packaging operation can eliminate the waste water by in-plant controls, such as re-use or recycle, and/or containment for evaporation, and have no discharge. This is routinely accomplished at many plants in this subcategory.

MODEL TREATMENT SYSTEMS

In order to allow an assessment of the economic impact of the limitations, model treatment technologies have been assumed that are capable of attaining the effluent levels specified by these limitations. Design and operating data from treatment systems existing in the industry form the basis for the model technologies described herein. These systems represent a way of attaining the recommended effluent limitations. Individual plants have many options available that are capable of attaining the effluent limitations such as the implementation of process modifications and in-plant control techniques, the use of alternate end-of-pipe technologies, and the use of alternate methods of disposal.

The following discussions describe the model treatment technologies which form the basis of the cost estimates to be used to assess the economic impact of the implementation of the recommended standards.

Subcategory 1--Organic Pesticide Chemicals

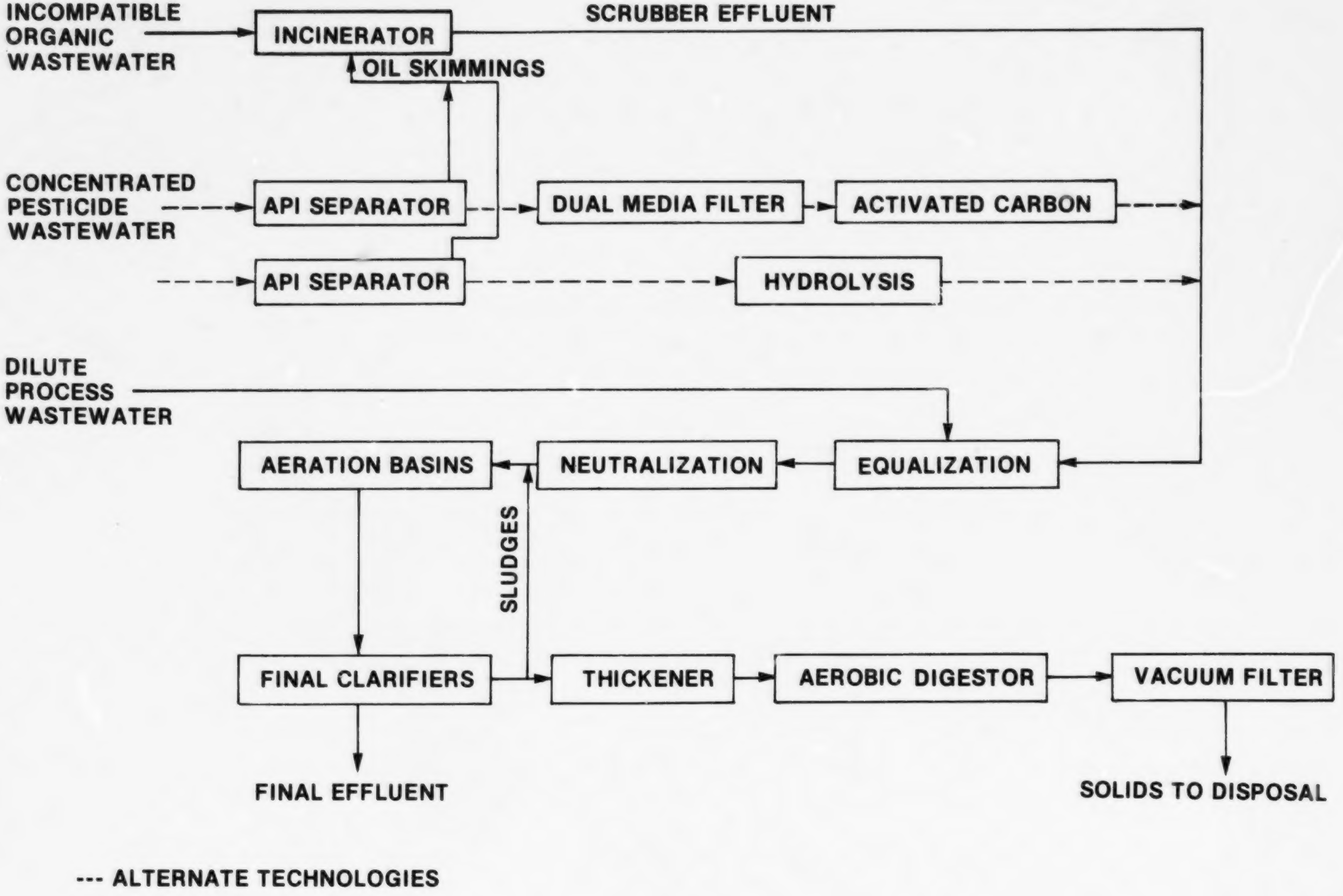
The technology recommended for Subcategory 1 manufacturers consists generally of pesticide chemicals removal through the application of hydrolysis or activated carbon techniques (any method that is applicable to the specific waste being treated should be considered), equalization, and biological treatment, coupled with incineration of incompatible waste streams. A flow diagram for this treatment system is presented in Figure VII-9.

Subcategory 2--Metallo-Organic Pesticide Chemical Manufacturers

The installation of additional technology is not anticipated at facilities where metallo-organic pesticide chemicals are manufactured. The current state-of-the-art is such that no discharge of process waste water pollutants is being achieved through the application of recycle technology.

Subcategory 3--Pesticide Chemical Formulators/Packagers

The model treatment technology for Subcategory 3 involves total evaporation of the small volume of waste water expected after implementation of a suitable process control system. Landfilling operations and contract-hauling are considered viable alternatives at Subcategory 3 plants.


INCOMPATIBLE ORGANIC WASTEWATER
INCINERATOR
SCRUBBER EFFLUENT
OIL SKIMMINGS
CONCENTRATED PESTICIDE WASTEWATER
API SEPARATOR
DUAL MEDIA FILTER
ACTIVATED CARBON
API SEPARATOR
HYDROLYSIS
DILUTE PROCESS WASTEWATER
AERATION BASINS
NEUTRALIZATION
EQUALIZATION
SLUDGES
FINAL CLARIFIERS
THICKENER
AEROBIC DIGESTOR
VACUUM FILTER
FINAL EFFLUENT
SOLIDS TO DISPOSAL
--- ALTERNATE TECHNOLOGIES

COST TREATMENT TECHNOLOGY
SUBCATEGORY 1

FIGURE VII-9

SECTION VIII

COST, ENERGY, AND NON-WATER QUALITY ASPECTS

GENERAL

The purpose of this section is to document the cost, energy, and nonwater quality aspects of the treatment technology presented in Section VII.

The costs presented are estimates of the capital and annual operating expenses expected to be required to attain the effluent limitations. They are based on the model end-of-line treatment techniques presented in Section VII applied to the raw waste load levels developed in Section V. The Agency does not require that this technology be installed at any plant location. However, the application of this technology will attain the effluent limitations presented in Section IX and, therefore, cost estimates are based on the model treatment technology. Individual plants have the option of utilizing process modifications, in-plant controls, alternate methods of disposal, alternate end-of-line treatment units, or any combination of the above in order to meet the guidelines. A separate economic analysis of treatment cost impact on the industry will be prepared and the results will be published in a separate document.

Annual and capital cost estimates have been prepared for end-of-pipe treatment technologies for each subcategory to be used in the evaluation of the economic impact of the recommended effluent limitations guildelines. The capital costs were generated on a unit process basis (e.g., equalization, neutralization, etc.). The total construction costs include the unit process costs, plus the following:

Item	Percent of Unit Process Capital Cost
Electrical	14
Piping	20
Instrumentation	8
Site Preparation	6

Engineering design and construction surveillance fees of 15 percent and contingencies of 15 percent were also assumed.

Since land costs vary so widely from location to location, the land requirements for each technology have been estimated so that

Preceding page blank

these costs can be considered separately in the economic impact analysis.

All cost data were computed in terms of July, 1977 dollars, which corresponds to an Engineering News Records Index (ENR) value of 2593. The bases for computation of capital and annual costs are presented in Tables VIII-1 and VIII-2.

DESIGN BASIS ON WHICH COST ESTIMATES ARE DERIVED

The following discussions present the design criteria which were assumed in the development of the costs of individual treatment modules. The designed factors are consistent with those used in the industry at plants where effluent levels equivalent to the recommended guidelines are being attained.

Segregation of Individual Streams

As previously noted, waste water segregation provides important technical and economic advantages. For example:

1. Waste streams not compatible with biological treatment (i.e., distillation tower bottoms or tars) are most effectively disposed of by incineration.

2. Activated carbon and hydrolysis techniques, employed to remove pesticides, are more cost-effective when applied to concentrated, segregated waste streams rather than to dilute, combined effluents.

3. High temperatures that may be required for hydrolysis can be more readily maintained on small volume waste streams.

4. Chemical costs for pH adjustment are smaller for concentrated waste streams.

Because these segregation techniques are widely recognized and practiced in the industry, they have been applied to the design basis of the model treatment technology. The pesticide removal unit processes have been sized for segregated waste streams approximately equal to one-third of the total plant flow based on current industry practice. As justification for this assumption, it is noted that the largest flows in the industry being treated by carbon and hydrolysis are approximately 150,000 gal/day and 175,000 gal/day respectively. The largest flow used for cost calculations, 300,000 gal/day, will have this upper range of reported values. It is further noted that plants currently

TABLE VIII--1

BASIS FOR COMPUTATION OF CAPITAL COSTS
(JULY 1977 DOLLARS)

CAPITAL COST ITEM	BASIS OF COMPUTATION
EXCAVATION	$5 per cubic yard
REINFORCED CONCRETE	$210 per cubic yard
EPOXY COATING FOR HYDROLYSIS BASIN	$2 per square foot
ACTIVATED CARBON SYSTEM BUILDING	
FOR 750 MIN. DETENTION	$35 per square foot of floor space
FOR 600 MIN. DETENTION	$35 per square foot of floor space
FOR 300 MIN. DETENTION	$30 per square foot of floor space
FOR 60 MIN. DETENTION	$30 per square foot of floor space
HYDROLYSIS BASIN ENCLOSURE	$7 per square foot
SITEWORK, ELECTRICAL, PIPING, AND INSTRUMENTATION	48% of total equipment cost
ENGINEERING	15% of construction cost
CONTINGENCY	15% of construction cost
EARTH WORK	$5 per cubic yard
CLEARING AND GRUBBING	$1,000 per acre
GRASSING AND MULCHING	$1.10 per square foot
LINER	
FOR LARGE EVAPORATION POND	$0.71 per square foot
FOR MEDIUM EVAPORATION POND	$0.77 per square foot
FOR SMALL EVAPORATION POND	$0.89 per square foot
CLEAR FIBERGLASS COVER	$2.00 per square foot
PIPINGS, FITTINGS, VALVES (for Subcategory 3)	20% of total equipment cost
ENGINEERING AND CONTINGENCY (for Subcategory 3)	15% of construction cost

TABLE VIII-2

BASIS FOR COMPUTATION OF ANNUAL COSTS (JULY 1977 DOLLARS)

ANNUAL COST ITEM	BASIS OF COMPUTATION
MAINTENANCE MATERIALS	4% of capital costs
TAXES AND INSURANCE	2% of capital costs
FERRIC CHLORIDE	\$0.20 per pound
CAUSTIC SODA, 50%	\$0.09 per pound
ACTIVATED CARBON	\$0.58 per pound
OPERATING LABOR	\$15,000 per man per year including fringe benefits
OPERATING SUPERVISION	\$20,000 per man per year including fringe benefits
CONTRACT HAULING AND DISPOSAL OF SLUDGE	\$5.00 per cubic yard
ELECTRICITY	\$0.05 per kilowatt-hour
THERMAL ENERGY	\$2.00 per million BTU \$0.28 for No. II fuel oil \$2.40 per 1000 lb steam
CAPITAL RECOVERY	Based on 10 years at 10%
MAINTENANCE, TAXES, AND INSURANCE (FOR SUBCATEGORY 3)	2% of capital costs

practicing or designing pesticide chemicals removal units pretreat only portions of their total flow: Plant 41-7.1 percent, Plant 49-38 percent, and Plant 21-10 percent.

It is recognized that pesticide chemicals within Subcategory 1 will differ in their resistance to removal through the application of activated carbon and hydrolysis technologies. For this reason, four different designs for each technology have been presented. This will allow all pesticide chemicals to be reduced to the same level, regardless of the degree of difficulty of removal of the individual pesticide(s).

API Separator

The API type separator is sized based on the following:

Temperature = 40°C
Rise rate of oil globules = 0.6 ft/min
Maximum allowable mean horizontal velocity = 2.4 ft/min

The API separator precedes either activated carbon or hydrolysis units. Skimmed organics are incinerated.

Dual Media Filter

A dual media pressure filter is provided in advance of the activated carbon columns. An influent pumping station loads the columns at a design rate of 4 gpm/ft^2. A terminal head loss of 10 ft is allowed. Backwash pumps operate for 12 minutes at 15 gpm/ft^2.

Activated Carbon Adsorption

A downflow, fixed-bed carbon system is assumed, including backwash pumps and a control building. Based on design characteristics presented in Table VII-3, contact times of 60, 300, 600, and 750 minutes have been assumed to demonstrate the range of costs potentially incurred. Hydraulic loading is assumed to be 0.5 gpm/ft^2. Carbon usage is assumed to be 100 lb per 1000 gal waste water treated. A minimum of two columns in series is provided, along with one carbon storage tank.

A regeneration facility is provided, including a furnace (feeder, scrubber, and after burner), spent carbon dewatering tank, slurry pumps, regenerated carbon wash tank, make-up carbon wash tank, and wash water pumps. An eight percent carbon loss during the regeneration step is assumed.

Hydrolysis

Hydrolysis units have been designed at four different detention times (200, 2000, 5000, and 12,000 minutes) in order to estimate costs for different degrees of difficulty in removing pesticide chemicals. These detention times are based on a reduction of ten half-lives, or 99.9 percent for pesticides for which data were available as identified in Tables VII-7 and VII-8. Chemical addition has been provided in order to raise the pH of the waste water from 7.0 to 11.0. Steam from available sources is employed to raise the waste water temperature from 22°C to 40°C. Mixing is provided at 30 hp per million gallons of volume. System components include: basins, mixers, caustic soda feeding and control, caustic storage tank, temperature control, steam delivery and control, and basin enclosure.

As noted under activated carbon, the design criteria for hydrolysis approximate actual operating conditions of plants capable of attaining effluent levels specified in the guidelines.

In order to insure that the design criteria were valid, hydrolysis data presented in Tables VII-7 and VII-8 were used to calculate the detention times required to achieve 99.9 percent removal. Since data were available at many different conditions of pH and temperature, it was necessary to standardize the data. The methodology utilized to predict the half-lives of all compounds at one set of conditions is described below.

The data were analyzed using the standard equations available for second order reactions. The second order rate constant is assumed to follow Arhenius' equation:

$$k_2 = Ae^{-E_a/RT}$$

where T = temperature (°K)
R = 1.987 cal/mole - °K
E_a = activation energy (cal/mole)
A = constant (l/mole-min)
k_2 = second order rate constant (l/mole-min)

The pseudo-first order rate constant is defined by the following equation:

$$k_1 = k_2 \times 10^{-pOH}$$

where $pOH = -\log(OH-)$
k_1 = pseudo-first order rate constant (min^{-1})

The half-life can be determined by dividing the natural log of 2 by the pseudo-first order rate constant:

$t\ (1/2) = (\ln 2)/k_1$ where, $t\ (1/2)$ = half-life (min)

In order to determine the half-life at any pH and temperature, it is necessary to know the values of the constants A and E_a/R in the Arhenius equation at the pH and temperature in question. It was assumed both that E_a/R does not vary significantly with pH, and that the natural log of A varies linearly with pH.

For each pesticide chemical where sufficient data were available, E_a/R and the relationship between A and pH were defined. These results were then used to produce tables showing the half-life at several temperatures and pH.

For each compound where insufficient data were available, a relative ease of hydrolysis factor was calculated. This is the quotient of the half-life of the compound divided by the half-life of a compound of similar structure for which data were available. This resulted in the production of a table of half-lives.

The half-life of any compound at any pH and temperature in the range in question can then be estimated using the tables of half-lives and the relative ease of hydrolysis factors.

The half-lives of several of the least and most readily hydrolizable compounds were determined and at pH 10, 11, and 12 at temperatures of 30, 40, and 50°C. From this information it was observed that pH = 11 and temperature = 40°C approximated optimal conditions.

The pesticide chemicals were then divided into four groups according to ease of hydrolysis:

Group 1: t (1/2) = 500 to 1200 min.

Group 2: t (1/2) = 200 to 500 min.

Group 3: t (1/2) = 20 to 200 min.

Group 4: t (1/2) = 20 min. or less.

Using the upper limit of each of the groups, the necessary detention time was determined for each group for 99.9 percent removal. These detention times were then used as the design basis of the treatment models.

Generally, pesticide hydrolysis proceeds by two mechanisms simultaneously. One mechanism is at neutral conditions and follows first order kinetics as defined by the following equation:

$$\underline{kN} = \underline{AN}e^{-En/RT}$$

Where En = activation energy for the neutral mechanism (cal/mole)
$\underline{AN}$ = constant for neutral mechanism (min)
$\underline{kN}$ = first order rate constant for neutral mechanism (min^{-1}).

The other mechanism is at alkaline conditions and follows second order kinetics as defined by the following equation:

$$\underline{kB} = (OH^-)\ \underline{AB}e^{-\underline{EB}/RT}$$

where $\underline{EB}$ = activation energy for the alkaline mechanism (cal/mole)
$\underline{AB}$ = constant for alkaline mechanism (1/mole-min)

(OH-) = pseudo - first order rate constant for alkaline mechanism (min^{-1})

The rate constant observed is the sum of the contributions of both mechanisms. Therefore,

$$k = k\underline{N} + k\underline{B}$$

where k = observed first order rate constant

These equations can be used to predict half-lives whenever data are available at two temperatures for both a neutral and an alkaline condition. The data in Tables VII-7 and VII-8 were analyzed according to second order kinetics.

For some pesticides, hydrolysis is catalyzed at acidic rather than alkaline conditions. Since the purpose of this effort was to estimate the costs of hydrolysis for pretreatment of pesticide wastes, acid hydrolysis was not costed in that alkaline hydrolysis would generally be more expensive and would yield representative cost data.

Incinerator

The design of the incinerator is based strictly on flow, as the heat release values of the waste are assumed negligible. Fuel requirements are based on a heat requirement of 0.5 million gm-cal/kg (1,000 BTU/lb) of waste. It was assumed that 1 percent of the total waste water flow is treated by incineration.

Equalization Basins

Equalization basins are sized for a holding time of 36 hours. The basin is equipped with a floating aerator with an energy requirement of 75 horsepower per million gallons of volume.

Neutralization Basin

The neutralization basin is sized on the basis of an average detention time of 6 minutes. Either acid or caustic neutralization may be required. For the purpose of cost estimation, caustic neutralization was assumed since it is the more expensive. The size of the caustic soda handling facilities is determined according to a 100 mg/l feed rate. Caustic soda storage is provided based on 30 days capacity. Caustic soda is fed by positive displacement metering pumps. Fifty horsepower per million gallons is provided for mixing.

Aeration Basins

The size of aeration basins is based on mixed liquor suspended solids and food to micro-organism ratios commonly used within the industry. Mechanical surface aerators are provided in the aeration basin. Aerators were selected on the basis of 2.0 pounds of oxygen per horsepower-hour.

Final Clarifiers

The clarifiers are assumed to be circular concrete basins with a depth of 12 feet. They are sized on the basis of an overflow rate of 400 gpd/sq ft. Allowance is made for a sludge return capacity of 200 percent.

Aerobic Digestor

The size of the aerobic digestor is based on a hydraulic detention time of 20 days. The size of the aerator-mixers is based on 150 horsepower per million gallons of digestor volume. A solids production of 0.6 kg VSS/kg BOD removed and a VSS reduction of 50 percent were assumed.

Sludge Thickener

The sludge thickener is designed on the basis of a solids loading of 10 lb/sq ft/day.

Vacuum Filtration

The size of the vacuum filters is based on a solids loading of 4 lb/sq ft/ hour with effluent solids at 15 pounds. Average running times of 12 hours are assumed. Chemical addition (ferric chloride) at a rate of 7 percent by weight of dry solids is provided.

Final Sludge Disposal

For all plants, sludge is assumed to be disposed of at a specially designated landfill.

Evaporation

The earthen evaporation ponds are designed for an evaporation rate of 21 inches per year. Pond depth of 4.0 feet including freeboard is assumed. The ponds are lined with plastic and covered with clear fiberglass roofing to prevent the entrance of rainfall. It is assumed that no mixing is required.

Control House

Included in the control house is space and equipment necessary for offices, lockers and showers, pumps, sample receiving, and a laboratory sufficient to monitor BOD, COD, TSS and pesticide chemicals.

COST CALCULATIONS

The following discussions present information relative to the estimation of capital and operating costs associated with the installation of the model treatment technology.

Subcategory 1 Cost Calculations

Cost estimates are presented to take into account the potential range of costs associated with the installation of the model treatment technology as defined in Section VII. The two principal factors affecting costs are the size of the treatment facilities and the degree of difficulty of pesticide removal.

The size of treatment facilities is affected by the volume of waste water to be treated. Based on information presented in Table V-10, costs relating to three plant sizes have been developed. The flow rates corresponding to the various plant sizes are as follows:

	Flow Rate	Production
Large plant	0.9 MGD	200,000 lb/day
Medium plant	0.2 MGD	45,000 lb/day
Small plant	0.045 MGD	10,000 lb/day

As discussed earlier in this section, the factors that relate directly to the degree of difficulty of pesticide removal are the contact time (activated carbon pretreatment technology) and the detention time (hydrolysis pretreatment technology). Four degrees of difficulty of pesticide removal are represented for both model pretreatment technologies. They are: (a) a contact time of 60, 300, 600, and 750 minutes for activated carbon and (b) a detention time of 200, 2000, 5000, and 12,000 minutes for hydrolysis. The pretreatment units are sized at one-third of the total plant flow, as discussed previously.

It has been assumed that the size and cost of biological treatment at any one flow is the same, regardless of the type of pretreatment employed. As explained in Section VII, activated carbon would in reality significantly reduce the wasteload of oxygen demanding materials to the biological system. However, the most effective type of pretreatment system cannot be determined without performing treatability studies; therefore, no reduction of non-pesticide pollutants has been assumed to ensure that the costs associated with the installation of biological treatment technology are not understated. Capital and annual costs of biological treatment (including equalization) are presented in Table VIII-3. The costs associated with pesticide removal units are not included.

Table VIII-4 presents sample capital and annual cost estimates for hydrolysis pretreatment. Table VIII-5 presents sample capital and annual cost estimates for activated carbon pretreatment. Table VIII-6 summarizes the capital and annual costs for pesticide removal. Table VIII-7 summarizes total capital and annual costs for pesticide and biological treatment.

Land costs may be added to the above totals by utilizing Table VIII-8 and multiplying by an appropriate land cost (dollars per acre).

Subcategory 2 Cost Calculations

No cost estimates have been developed for this subcategory. The state-of-the-art at plants manufacturing metallo-organic pesticide chemicals is no discharge of process waste water pollutants. It was originally reported that all plants were "no discharge" facilities; however, representatives of one facility (plant 19) recently indicated that there is a discharge from their manufacture of metallic-organo pesticide chemicals. This is being investigated by the Agency. The overall impact to this subcategory is expected to be minimal.

Subcategory 3 Cost Calculations

Table VIII-9 itemizes the capital and operating costs associated with total evaporation of the waste water generated from formulating and packaging operations. Three plant sizes are considered that correspond to the following waste water flow rates:

Large plant	5000 GPD
Medium plant	500 GPD
Small plant	50 GPD

The quantities of land necessary to install the model treatment technology, as defined in Section VII, are 1.76, 0.18, and 0.02 acres for the large, medium, and small plants, respectively. Land costs may be calculated by multiplying these figures by an appropriate land cost (dollars per acre).

TABLE VIII-3

BPT COST ITEMIZATION
EXCLUDING PESTICIDE REMOVAL UNITS
SUBCATEGORY 1

	Large Plant	Medium Plant	Small Plant
Average Production 1000 lb/day	200	45	10
Wastewater Flow MGD	0.9	0.2	0.045
Capital Costs			
Incinerator	$275,960	$176,790	$100,250
Influent Pump Station for Concentrated Waste	28,500	21,500	19,500
Influent Pump Station for Dilute Waste	38,000	23,500	19,800
API Separator	59,750	33,920	24,700
Equalization	360,000	142,000	65,000
Transfer Pump Station	47,000	25,500	20,500
Neutralization	53,530	35,680	29,830
Transfer Pump Station	47,000	25,500	20,500
Aerator	475,000	146,000	44,800
Clarifier	355,500	190,000	103,000
Aerobic Digestor	305,000	115,000	38,500
Sludge Thickener	197,000	128,000	82,000
Vacuum Filter	148,000	84,000	47,300
Control Building	87,680	87,680	87,680
Monitoring Station	16,390	16,390	16,390

TABLE VIII-3 (con't)

Subtotal (including sitework, electrical, piping, and instrumentation	2,493,810	1,251,460	719,750
Engineering & Contingency	748,140	375,440	215,920
Total Capital Cost	3,241,950	1,626,900	935,670
Annual Cost:			
Capital Recovery	528,440	265,180	152,510
Operating/Maintenance	430,770	176,620	85,560
Energy/Power	181,170	46,140	16,480
Total Annual Cost	1,140,380	487,940	254,550

TABLE VIII-4

BPT COST ITEMIZATION
HYDROLYSIS--12,000 MINUTES DETENTION
SUBCATEGORY 1

	Large Plant	Medium Plant	Small Plant
Average Production 1000 lb/day	200	45	10
Wastewater Flow MGD	0.3	0.067	0.015
Capital Costs			
Basin	$ 810,630	$ 215,580	$ 77,260
Mixers	63,420	14,780	9,580
Caustic Soda Feeding and Control	22,330	22,330	22,330
Caustic Storage Tank	10,440	4,380	1,460
Temperature Control	7,500	7,500	7,500
Steam Delivery and Control	12,190	8,120	4,400
Subtotal	926,510	272,690	122,530
Site Work, Electrical, Piping and Instrumentation	444,720	130,890	58,810
Subtotal	1,371,230	403,580	181,340
Engineering & Contingency	411,370	121,070	54,400
Total Capital Cost	1,782,600	524,650	235,740
Annual Cost:			
Capital Recovery	290,560	85,520	38,430
Operating/Maintenance	147,330	42,580	19,530
Energy/Power	100,270	23,910	5,960
Total Annual Cost	538,160	152,010	63,920

TABLE VIII-5

BPT COST ITEMIZATION
CARBON--750 MINUTES DETENTION
SUBCATEGORY 1

	Large Plant	Medium Plant	Small Plant
Average Production 1000 lb/day	200	45	10
Wastewater Flow MGD	0.3	0.067	0.015
Capital Costs			
Adsorption System	$2,101,710	$ 475,370	$ 160,070
Regeneration System	1,034,260	393,310	179,170
Subtotal	3,135,970	868,680	339,240
Site Work, Electrical, Piping and Instrumentation	1,505,270	416,970	162,840
Subtotal	4,614,240	1,285,650	502,080
Dual Media Filter	144,000	93,000	87,000
Influent Pump Station	25,800	21,500	19,500
Subtotal	4,784,040	1,400,150	608,580
Engineer and Contingency	1,435,210	420,040	182,570
Total Capital Cost	6,219,250	1,820,190	791,150
Annual Cost:			
Capital Recovery	1,013,740	296,690	128,960
Operating/Maintenance	1,283,950	448,640	200,260
Energy/Power	144,870	25,210	9,660
Total Annual Cost	2,442,560	770,540	338,880

TABLE VIII-6

BPT COST SUMMARY
PESTICIDE REMOVAL
SUBCATEGORY 1

	Retention Time, Minutes		Large Plant	Medium Plant	Small Plant
Hydrolysis	12,000	Capital	$1,782,600	$ 524,650	$235,740
		Annual	538,160	152,010	63,920
	5,000	Capital	860,040	293,320	164,630
		Annual	329,300	97,130	47,410
	2,000	Capital	448,810	202,810	115,250
		Annual	219,390	74,650	36,070
	200	Capital	172,430	110,760	83,930
		Annual	153,320	53,300	28,920
Carbon	750	Capital	6,219,250	1,820,190	791,150
		Annual	2,442,560	770,540	338,880
	600	Capital	5,293,610	1,558,090	727,000
		Annual	2,230,950	711,810	324,390
	300	Capital	4,256,620	1,418,480	648,540
		Annual	1,999,700	680,680	306,890
	60	Capital	3,079,490	1,167,620	575,110
		Annual	1,734,840	624,350	290,510

TABLE VIII-7

BPT COST SUMMARY
ALL TREATMENT UNITS
SUBCATEGORY 1

Item: Biological System		Large Plant	Medium Plant	Small Plant
Including Hydrolysis	Capital	$5,024,550	$2,151,550	$1,171,410
12,000 Min. Detention	Annual	1,678,540	639,950	318,470
5,000 Min. Detention	Capital	4,101,990	1,920,220	1,100,300
	Annual	1,469,680	585,070	301,960
2,000 Min. Detention	Capital	3,690,760	1,029,710	1,050,920
	Annual	1,359,770	562,590	290,620
200 Min. Detention	Capital	3,414,380	1,737,660	1,019,600
	Annual	1,293,700	541,240	283,470
Including Carbon	Capital	9,461,200	3,447,090	1,726,820
750 Min. Detention	Annual	3,582,940	1,258,480	593,430
600 Min. Detention	Capital	8,535,560	3,184,990	1,662,670
	Annual	3,371,330	1,199,750	578,940
300 Min. Detention	Capital	7,498,570	3,045,380	1,584,210
	Annual	3,140,080	1,168,620	561,440
60 Min. Detention	Capital	6,321,440	2,794,520	1,510,780
	Annual	2,875,220	1,112,290	545,060

TABLE VIII-8

LAND REQUIREMENTS
SUBCATEGORY 1

Item	Land Area in Acres		
	Large Plant	Medium Plant	Small Plant
Incinerator	0.19	0.11	0.05
Influent Pump Stations	0.10	0.06	0.03
API Separator	0.07	0.03	0.01
Equalization	0.19	0.11	0.05
Transfer Pump Station	0.10	0.06	0.03
Neutralization	0.19	0.11	0.05
Transfer Pump Station	0.10	0.06	0.03
Aeration	0.24	0.12	0.05
Clarifier	0.24	0.12	0.05
Aerobic Digestor	0.33	0.17	0.08
Sludge Thickener	0.10	0.06	0.03
Vacuum Filter	0.10	0.06	0.03
Control Building	0.30	0.30	0.30
Monitoring Station	0.05	0.05	0.05
Total Land Requirement	2.30	1.42	0.84
Hydrolysis,- 12,800 Min. Detention	1.29	0.35	0.13
Hydrolysis - 5,000 Min. Detention	0.53	0.18	0.08

TABLE VIII-8 (cont'd)

Hydrolysis - 2,000 Min. Detention	0.28	0.10	0.05
Hydrolysis - 200 Min. Detention	0.06	0.03	0.03
Carbon - 750 Min. Detention	0.98	0.27	0.09
Carbon - 600 Min. Detention	0.95	0.25	0.08
Carbon - 300 Min. Detention	0.90	0.22	0.07
Carbon - 60 Min. Detention	0.82	0.18	0.06

TABLE VIII-9

BPT COST ITEMIZATION
SUBCATEGORY 3

	Large Plant	Medium Plant	Small Plant
Wastewater Flow (GPD)	5,000	500	50
Capital Costs			
Evaporation Pond			
Earth Work	$ 25,820	$ 2,580	$ 260
Clearing and Grubbing	2,400	240	20
Grassing and Mulching	25,260	7,940	2490
Liner	56,920	5,690	570
Clear Fiberglass Cover	139,429	13,940	1400
Pump Station	19,000	4,600	1500
SUBTOTAL	268,820	34,990	6240
Piping, Fittings and Valves	53,760	7,000	1250
SUBTOTAL	322,580	41,990	7490
Engineering and Contingency	48,390	6,300	1120
TOTAL CAPITAL COST	370,970	48,290	8610
Annual Cost			
Capital Recovery	60,470	7,870	1400
Operating/Maintenance	7,420	970	30
Energy/Power	270	270	270
TOTAL ANNUAL COST	68,160	9,110	1700

NON-WATER QUALITY ASPECTS

The non-water quality aspects of the implementation of the recommended effluent limitations is directly affected by the various methods employed to treat and dispose of pesticide chemicals waste waters prior to discharge to surface waters. The impacts of major importance are related to air and solid waste considerations. Another area of concern involves protection of groundwater.

Air Considerations

Incineration is a widely used technology in the pesticide chemicals industry for combustion of highly concentrated organic or toxic wastes. Since the off-gases from incineration can be adequately controlled by scrubbing, with the resultant effluent being discharged to the waste water treatment facility, air quality impact need not be significant.

Equipment requirements for control of air pollutant emissions vary for different applications, waste characteristics, incinerator performance, and air pollutant emission standards. Particulate matter can be controlled by the use of cyclones, bag filters, electrostatic precipitators, or venturi scrubbers. Emissions from combustion of wastes containing halogen, sulfur, or phosphorus compounds require the use of aqueous (water or alkaline solution) scrubbing. Incineration is not applicable to organic pesticides containing heavy metals such as mercury, lead, cadmium, or arsenic, nor is it applicable to most inorganic pesticides or metallo-organic pesticides which have not been treated for removal of heavy metals.

Land Disposal Considerations

In all cases where incineration is used, provisions must be made to ensure against the dispersal of hazardous pollutants into the atmosphere. The disposal of solid wastes generated through the implementation of water pollution control technology must be done with proper management. The quantities of sludge generated at subcategory 1 plants employing the model treatment technology (as defined in Section VII) are estimated to be:

	PLANT SIZE kl/day (MGD)	DRY SOLIDS GENERATED kkg/day
Large	3410 (0.9)	1.51
Medium	760 (0.2)	0.335
Small	170 (0.045)	0.0754

Lime and biological sludges are generally compatible with ultimate disposal in a specially designated landfill. However, if land disposal is to be used for materials considered to be hazardous, the disposal sites must not allow movement of pollutants to either ground or surface waters. Natural conditions which must exist include geological insurance that no hydraulic continuity can occur between liquids and gases from the waste and natural ground or surface waters. Disposal areas cannot be subject to washout, nor can they be located over active fault zones or where geological changes can impair natural barriers. Any rock fractures or fissures underlying the site must be sealed.

As a safeguard, liners are often needed at landfill sites. Liner materials, consisting of clay, rubber, asphalt, concrete, or plastic, should be pre-tested for compatability with the wastes.

Leachate from the landfill must be collected and treated. Treatment, which will of course vary with the nature of the waste, may consist of neutralization, hydrolysis, biological treatment, or evaporation. Treatment in some cases may be achieved by recycling the leachate into the landfill.

Landfills for the disposal of hazardous wastes are generally operated under some form of permit from a state agency. The regulations and restrictions vary from state to state.

Encapsulation prior to landfilling is recommended for certain materials such as those containing mercury, lead, cadmium, and arsenic, and for organic compounds which are highly mobile in the soil (Federal Register, May 1, 1974, pp 15236-15241).

Where practicable, provision for separate storage of different classifications of pesticides according to their chemical type, and for routine container inspection, should be considered.

In general, pesticides or pesticide wastes should only be disposed of at a "specially designated" landfill, which is defined as "a landfill at which complete long term protection and subsurface waters... and against hazard to public health and the environment. Such sites should be located and engineered to avoid direct hydraulic continuity with surface and subsurface waters, and any leachate or subsurface flow into the disposal area should be contained within the site unless treatment is provided. Monitoring wells should be established and a sampling and analysis program conducted. The location...should be permanently recorded in the appropriate office of legal jurisdiction" (Federal Register, May 1, 1974, pp 15236-15241).

Off-site disposal is commonly practiced in the industry for highly concentrated wastes. It is also common practice for formulation plants with very low waste water generation to haul their waste water to other plants that have treatment systems. Land disposal of residuals should be in conformance with all applicable federal, state, and local ordinances.

The hauling of pesticide wastes requires special handling equipment and/or prior containerization.

Activated carbon adsorption can be considered as a land-related treatment method since in some applications the spent carbon is disposed of by containerization and surface storage. Also, thermal regeneration of carbon may be regarded as an incineration method and subject to the above discussion of incineration.

Protection of Groundwater

Deep-well injection has been considered economically attractive and is employed at several plants in the pesticide chemicals industry. A deep-well disposal system can only be successful if a porous, permeable formation of a large area and thickness is available at sufficient depth to insure continued, permanent storage. It must be below the lowest ground water aquifer, be confined above and below by impermeable zones (aquicludes), and contain no natural fractures or faults. The waste water so disposed must be physically and chemically compatible with the formation, and should be completely detoxified prior to injection. Suspended solids which could result in stratum plugging must be removed. Well construction must provide adequate protection against groundwater contamination and include provisions for continuous monitoring of well performance and subsurface movement of wastes, including continuous sampling by monitor wells. Very few deep well injection systems meet all these requirements.

Evaporation ponds may consist of concrete or earthen basins. In the latter case, unless the natural soil is impervious, lining with an impervious material is necessary to ensure that groundwater is protected.

SECTION IX

BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE EFFLUENT LIMITATIONS GUIDELINES

The effluent limitations which must be achieved by July 1, 1977, specify the degree of effluent reduction attainable through the application of the Best Practicable Control Technology Currently Available (BPT). BPT is generally based upon the average performance of the best existing treatment plants of various sizes, ages, and unit processes within the industrial category and/or subcategory. Consideration must also be given to:

a. The total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application;

b. The size and age of equipment and facilities involved;

c. The process employed;

d. The engineering aspects of the application of various types of control techniques;

e. Process changes;

f. Non-water quality environmental impact (including energy requirements);

g. Availability of land for use in waste water treatment-disposal.

BPT emphasizes treatment facilities at the end of a manufacturing process, but includes the control technologies within the process itself when these are considered to be normal practices within the industry.

A further consideration is the degree of economic and engineering reliability which must be established for the technology to be "currently available." As a result of demonstration projects, pilot plants, and general use, there exists a high degree of confidence in the engineering and economic practicability of the technology presented in this document.

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Based upon the information contained in Sections II through VIII of this document it has been determined that the degree of effluent level attainable through the application of the best practicable control technology currently available is that listed in Table IX-1. Pesticide chemicals are the sum of all regulated active ingredients produced in a plant. The pH of the effluent must be in the range of 6.0 to 9.0.

SUMMARY OF GUIDELINES DEVELOPMENT SUBCATEGORY 1

The effluent limitations guidelines are based on an analysis of the long term effluent data obtained from existing treatment plants which have the model treatment, i.e., pesticide removal, equalization, and biological treatment that are properly operated. The limitations are the product of the long term average performance and a daily maximum or a 30-day maximum variability factor.

The data base used to set the limitations for subcategory 1 was derived in the following manner. There are 29 known pesticide manufacturing plants that discharge process waste water directly. The products at four plants (33, 36, 53 and 153) were excluded from coverage at this time. Plant 9 is closed and no data were used. Plants 11, 15, 16, 31, 40 and 155 have neither biological nor pesticide removal treatment. No data from these plants were used to derive the limitations.

The derivation of the pesticide chemicals limitations will be described first. Data from Plants 29, 41, 47, 48, 146 and 149 were not used as they had no pesticide treatment. Of the remaining plants only those with pesticide removal treatment as described in Section VII were used to determine the pesticide limitations. These are plants 3, 8, 18, 19, 21, 22, 27, 32, 34, 39, 45 and 50. The data from Plants 6, 20 and 28, which discharge to publicly owned treatment works, were included because adequate pesticide removal treatment is practiced prior to discharge.

Plant 18 did not have data on pesticide levels and was not further considered. Effluent data and operating conditions were not supplied by Plant 22, and it was not further considered. Plant 34 did not detect pesticide active ingredients in the effluent, and these data were not used. Data from Plant 32 was not included since it does not have adequate treatment as described in Section VII. Plant 50 only treats floor washings. These data are not representative of typical manufacturing

TABLE IX-1

SUBCATEGORY[1]	EFFLUENT CHARACTERISTIC	EFFLUENT LIMITATIONS: AVERAGE OF DAILY VALUES FOR 30 CONSECUTIVE DAYS	EFFLUENT LIMITATIONS: DAILY MAXIMUM
1	BOD_5	1.6	7.4
	COD	9.	13.
	TSS	1.8	6.1
	Pesticide Chemicals	.0018	0.010
	pH[2]	-	-
2	------NO DISCHARGE OF PROCESS WASTE WATER POLLUTANTS---------		
3	------NO DISCHARGE OF PROCESS WASTE WATER POLLUTANTS---------		

Note: All units are kg/kkg

1. Subcategory 1: Organic Pesticide Chemicals Manufacturing
   Subcategory 2: Metallo-Organic Pesticide Chemicals Manufacturing
   Subcateogry 3: Pesticide Chemicals Formulating and Packaging

2. The pH shall be between the values of 6.0 to 9.0

process waste water and were not used. Plant 19 uses activated carbon to remove free chlorine rather than pesticide, hence these data were not used.

The limitations for BOD, COD and TSS are based on the model of biological treatment. Of the twenty-five direct dischargers that are regulated, thirteen plants have biological treatment. These are Plants 19, 21, 22, 27, 29, 32, 34, 39, 41, 47, 48, 146 and 149. Plant 28 discharges to a public owned treatment system but has the recommended technology in place. However, since TSS is not of major concern to the receiving treatment plant, the TSS removal technology is not as elaborate as for direct dischargers. Hence, the BOD5 and COD data were used and the TSS data was not used.

Plants 3, 8, 18, 45 and 50 do not have biological treatment and they were not used to determine the biological parameter limitations. Plants 22, 27, 29, 47, 146, and 149 either do not monitor BOD, COD or TSS or did not supply this data when requested by the Agency. Plants 34 and 39 submitted BOD, COD and TSS data only after the pesticide removal treatment. No effluent discharge data were supplied from the biological system for these two plants. These data for BOD, COD and TSS were therefore not used. Plant 48 supplied estimates for BOD, COD and TSS. These data were not included. Plant 32 as described in Section VII has inadequate treatment and these data were not included.

The BOD limitations are derived from plants 19, 21, 28 and 41. The COD limitations are derived from plants 19, 28 and 41. Plant 21 does not monitor for COD. The TSS limitations are derived from Plants 19, 21, and 41.

Long-term averages

Subcategory 1 long-term average effluent data are presented in Table IX-2. Long-term averages represent the average discharge in units of daily average pounds of pollutants per average 1000 pounds of pesticide chemicals produced for the period for which effluent data were available from the plants. The overall long-term average has been weighted according to the number of observations available, so that the contribution of a particular plant's data is in proportion to the number of observations from the plant.

All data supplied to the Agency from plants that currently employ and properly operate the model technology were utilized in developing long-term averages. These data, and the weighted long-term averages are presented in Table IX-2.

TABLE IX-2

DEVELOPMENT OF LONG TERM AVERAGES
SUBCATEGORY 1

PLANT	PARAMETER (NUMBER OF OBSERVATIONS) BOD (n)	COD (n)	TSS (n)	PESTICIDE CHEMICALS (n)
3	-	-	*	0.000943 (244)
6	*	*	*	0.000505 (5)
8	*	*	*	0.0000765 (25)
19	2.53 (34)	19.4 (28)	1.17 (28)	**
20	*	*	*	0.00300 (185)
21	1.11 (334)	-	1.36 (329)	0.000762 (314)
27	-	-	-	0.00315 (52)
28	0.541(65)	7.01 (450)	***	0.0007 (450)
39	*	*	*	0.000162 (4)
41	1.00 (60)	10.2 (61)	1.08 (61)	**
45	*	*	*	0.031 (5)
Weighted Average	1.12 (482)	8.01 (539)	1.31 (418)	0.00129 (1284)

Note: All values are kg/kkg
* = Available data do not include biological treatment
** = Available data do not include pesticide removal
*** = Data from biological treatment prior to clarification
- = No data available
(n) = Number of data points

For Subcategory 1, zero discharge facilities were not used in the computation of the limitations. Plants, at which no detectable levels of pesticides were found, were not used to determine the limitations.

The long term averages of plants used to develop the effluent limitations are not based on deep well injection. If process waste water from the production of an active ingredient is disposed into a well, the production of that active ingredient should not be included in the calculation of discharge levels for pesticide chemicals.

Development of variability factors

During the development of the interim final limitations guidelines the Agency used a procedure based on fitting the three parameter log normal distribution to the effluent data to determine the variability factors. Subsequent goodness-of-fit tests on the expanded data base failed to justify the universal applicability of the normal, two parameter lognormal or three parameter lognormal distributions to describe the data. Hence, the Agency adopted the distribution free procedures described below.

The results of the daily and 30-day variability analyses are presented in Table IX-3. Pesticide data being monitored at the effluent of activated carbon or hydrolysis pretreatment, such as at Plant 20, were not included in the analyses.

Data from plants which did not supply sufficient numbers (more than 90) of observations to determine variability factors with specified confidence levels were not used. Hence, the data from plants 6, 8, 20, 27, 39 and 45 were not used to determine the variability factors for pesticide chemicals. This was also the case for Plant 19 for BOD, COD and TSS and Plant 28 for BOD.

Variability factors at each plant were weight-averaged in the same manner as the long term values to arrive at one factor for each parameter. When these factors are multiplied by the long term values established in Table IX-2, the daily maximum effluent limitations guidelines given in Table IX-1 result.

Daily Maximum Factor

The daily maximum variability factor is defined as an estimate of K.99, the 99th percentile of the distribution of daily pollutant discharge, divided by the average daily pollutant discharge. Given a set of daily observations the daily variability factor is

TABLE IX-3

VARIABILITY FACTORS
SUBCATEGORY 1

PLANT	DAILY MAXIMUM PARAMETERS			
	BOD(n)	COD(n)	TSS(n)	PESTICIDE CHEMICALS (n)
3	-	-	*	9.4 (244)
21	7.7 (354)	-	5.4 (360)	5.0 (341)
28	-	1.8 (92)	-	12.2 (92)
41	2.6 (95)	1.5 (121)	2.5 (122)	
Weighted Average	6.6 (449)	1.6 (213)	4.7 (482)	7.6 (677)

PLANT	30-DAY MAXIMUM			
	BOD(n)	COD(n)	TSS(n)	PESTICIDE CHEMICALS (n)
3	-	-	*	1.5 (244)
21	1.5 (354)	-	1.4 (360)	1.3 (341)
28	-	1.2 (92)	-	1.6 (92)
41	1.2 (95)	1.1 (121)	1.2 (122)	
Weighted Average	1.4 (449)	1.2 (213)	1.3 (482)	1.4 (677)

n = number of observations

- = No data available
* = Available data do not include biological treatment

$U.99/X$

where

$U.99$ = an estimate of $K.99$
X = arithmetic average of the daily observations

The value for U.99 was obtained as the rth smallest (where r was less than or equal to n) sample value, denoted by X(r), chosen so that the probability that X(r) is greater than or equal to K.99 was at least 0.50. The value of r for which this criterion was satisfied was determined by nonparametric methods (see, e.g., J. D. Gibbons, Nonparametric Statistical Inference, McGraw-Hill, 1971). An estimate chosen in this manner is sometimes referred to as a 50% reliable estimate for the 99th percentile and is interpreted as the value below which 99% of the values of a future sample of size n will fall with probability 0.50.

In some cases the number of observations available from a plant were not sufficient to obtain a nonparametric 50% reliable estimate of the 99th percentile. In those cases the plant's data were not used in the calculation of the overall variability factors.

30 Day Maximum Variability Factors

The 30 day maximum variability factors were derived on the basis of the statistical theory which holds that the distribution of the mean of a sample drawn from a population distributed according to any one of a large class of different distributional forms will be approximately normal. In applying the central limit theory to the derivation of 30 day variability factors, the sample mean is the average of 30 daily discharge measurements and the underlying population is the daily discharge. For practical purposes, the normal distribution provides a good approximation to the distribution of the sample mean for samples as small as 25 or 30 (see, e.g., Miller and Fruend, Probability and Statistics for Engineers, Prentice-Hall, 1965, pp. 132-34). This approach is distribution free in the sense that no restrictive assumption is made regarding the form of the population distribution and is thus consistent with the method used to derive the daily maximum variability factors. The approach is also in agreement with industry comments to the effect that 30 day limitations can be based on this theory.

The 30 day maximum variability factors were calculated as follows:

$$\text{30 day maximum factor} = \frac{X + 2.33\ S/\ 5.477}{X}$$

where

X = average daily discharge in pounds
S = standard deviation of the daily discharge observations

Since 5.477 is approximately the square root of 30, the quantity S/5.477 is an estimate of the standard deviation of the mean of a sample of size 30 drawn from a population with mean X and standard deviation S. The numerator of the 30 day variability factor is an estimate of the 99th percentile of the distribution of the mean of a sample of size 30 from a population with mean x and standard deviations. Data not included in the overall average daily maximum variability factors were not included in the average 30 day variability factors.

Although the regulations are based on a 99 percentile, the methodology employed in determining the limitations is sufficiently conservative that the limits should not be exceeded by a properly operated treatment system. In fact, many of the best plants have not exceeded the limits.

Subcategory 2

Subcategory 2 manufacturers demonstrate the practice of no discharge of pollutants via in-process control and recycle of waste waters.

Subcategory 3

Subcategory 3 formulators and packagers demonstrate the practice of no discharge of pollutants via in-process control and total evaporation.

Summary of Point Source Discharges

The Agency believes that the regulations presented in this document are presently or will shortly be attained by sixteen of the twenty-five affected dischargers. These sixteen plants will meet the regulations by either the model technology, alternate treatment technologies or predicted performance from treatment systems scheduled to be completed prior to the expiration of existing NPDES permits.

Two of the direct dischargers have not supplied adequate data for the Agency to make a determination at this time. These plants are being investigated further. The indication is that these plants have inadequate treatment but no firm statement can be made from data supplied by these plants. The remaining seven direct dischargers are expected to incur some cost to comply with the final regulations. These costs are in the form of capital and operating costs and are itemized in Table IX-4.

The Agency recognizes that certain conditions may exist which prevent the monitoring of pesticides at the required levels. For example, a plant producing a pesticide will receive an allowance (lbs) which may require monitoring below current detection limits, depending on the amount of dilution by other processes in the plant.

In situations such as these several options are available in applying the limitations. First, the analytical method employed by the plant should be verified with the Environmental Monitoring and Support Laboratory, Cincinnati. Second, sampling may be done prior to the dilutions. If the pesticide is being removed in a particular pretreatment unit (activated carbon, hydrolysis, etc.), concentrations immediately following that unit operation may lie within the detectable range. If the pesticide (lb/1000 lbs) measured at this point is below the levels required, then the plant has obviously complied with the intention of the regulations, assuming no pesticide contaminated wastes are introduced downstream from this point. If the pesticide level (lb/1000 lbs) following pretreatment is greater than allowed by the regulation, then the degree of removal through the biological system must be determined. The pathway and biological degradation of the pesticide may require determination by independents means. Treatability studies or in-depth sampling may be required to establish the portion of the pesticide adsorbed onto the sludge, versus that which remains in the supernatant. The potential for build-up of pesticides in the treatment system should also be recognized.

ENGINEERING ASPECTS OF CONTROL TECHNOLOGY

As discussed in Section VII, a variety of treatment models other than those discussed in this document may be employed in the industry. For particular installations, other models could be more cost effective. This can only be determined on a case by case basis.

Application of the best practicable control technology currently available does not require major changes in existing industrial processes for the subcategories studied. Water conservation practices, improved housekeeping and product handling practices, and improved maintenance programs can be incorporated at virtually all plants within a given subcategory.

TABLE IX-4

UPGRADING OF EXISTING SYSTEMS ANTICIPATED TO ATTAIN LIMITS

Plant	Additional Treatment Required	Additional Capital Costs	Additional Annual Costs
3	None	None	None
8	None	None	None
9	None	None	None
11	None	None	None
15	Unknown-Awaiting 308 Responses	Unknown	Unknown
16	None	None	None
18	None	None	None
19	Activated Carbon and Sand Filtration	$ 460,000	$ 450,000
21	Hydrolysis(Nitrogen Pesticides)	$ 430,000	$ 202,000
22	None	None	None
27	Sand Filtration	$ 167,400	$ 58,900
29	None	None	None
31	None	None	None
32	Hydrolysis, Tertiary Sand Filtration and Activated Carbon	$6,221,000	$3,075,700
33	None Applicable Excluded Products	None	None
34	None	None	None
36	None Applicable Excluded Products	None	None
39	None	None	None

TABLE IX-4

UPGRADING OF EXISTING SYSTEMS ANTICIPATED TO MEET LIMITS
CONTINUED, PAGE 2 OF 2 PAGES

Plant	Additional Treatment Required	Additional Capital Costs	Additional Annual Costs
40	None	None	None
41	Activated Carbon	$1,650,000	$780,000
45	None	None	None
48	Activated Carbon	$ 980,000	$445,000
47	None	None	None
50	None	None	None
53	Not Applicable - Excluded Product	None	None
146	Activated Carbon	None-lease	$ 55,000
149	Unknown Awaiting 308 Response	Unknown	Unknown
153	Not Applicable Excluded Product	None	None
155	None	None	None

The technology to achieve these recommended effluent limitations is practiced within the subcategories under study or can be readily transferred from technology in other industries. The concepts are proven, available for implementation, and applicable to the wastes in question. However, up to two years may be required from design initiation to plant start-up. These waste treatment techniques are also broadly applied within many other industries. The technology utilized may necessitate improved monitoring of waste discharges and of additional waste treatment components on the part of some plants, and may require more extensive training of personnel in the operation and maintenance of waste treatment facilities. However, these procedures are currently practiced in some plants and are common practice in many other industries.

FACTORS TO BE CONSIDERED IN APPLYING EFFLUENT GUIDELINES

Land Availability

The above assessment of what constitutes the best practicable control technology currently available is predecated on the assumption of a degree of uniformity among plants within each subcategory that does not necessarily exist in all cases. One of the more significant variations that must be taken into account in applying limitations is availability of land for retention and/or treatment of waste water. While the control technologies described herein have been formulated for minimal land requirements, individual cases of extreme lack of land may present difficulties in applying these technologies. In other cases, the degree of land availability may dictate one treatment alternative over another, or allow treatment costs to be considerably less than those presented.

Production-Discharge Correlation

There are several instances in which no correlation may exist between the final effluent and the unit of production on a short term basis due to the batch nature of the process or to the cleanup periods. For example, while a plant is synthesing pesticides in a batch process, virtually no waste water may be generated. During a subsequent period of time, however, production operations may have completely ceased but a considerable amount of waste water may be generated by clean-up procedures. In such cases, it is recommended that plant capacity, measured on a long term basis, be used in applying the limitations.

Multiple Products

Another production factor which should be considered is that of intermediate products. The problem might best be illustrated by three idealized plants:

Plant A receives certain raw materials, processes them through a number of steps (with each step generating waste water and resulting in intermediate products which are used in the subsequent step), and ultimately produces final pesticide products. The total waste water generated by Plant A can be related to the quantity of final product, and theoretically other plants such as Plant A producing the same final products would generate similar waste water loadings per unit product.

Plant B is similar to Plant A in that it produces the same final products, but it differs in that it produces more intermediate than is required and consequently sells a portion. In this case, if only the final products are considered and the intermediates ignored, the waste water loading per product unit could be substantially higher than that of Plant A.

Plant C also produces the same final products as Plants A and B, but it purchases some of the intermediate products and thereby eliminates certain processing steps and the corresponding waste water generation. In this case, the waste water loading per product unit could be substantially lower than that of Plant A.

These limitations exclude the coverage of intermediates. In order to evaluate data from plants such as A, B, and C above, the influent or effluent mass loading (lbs) has been divided by the total plant production (pesticides, intermediates, and non-pesticides, if applicable). The assumption that the above processes contribute equally to waste loading has only been made when monitoring is insufficient to establish any other proportion.

There are pesticide manufacturing facilities that also do formulating and packaging and have a common treatment system. Such plants should receive no credit for formulating and packaging. The limitations should be calculated based on the manufacturing production only.

Storm Runoff

In all cases herein, including those for which no discharge of waste waters is recommended, it must be recognized that storm runoff can contain various degrees of contamination. Except for very new installations, many pesticide plants have contaminated soil resulting from past spills. Runoff or leachate from that soil may exhibit contamination, even in cases where there is no discharge of process waste water. Extra allowance for this may be allowed.

SECTION X

LIST OF COMMON PESTICIDE COMPOUNDS BY SUBCATEGORY

In order to provide readers with a convenient cross reference, Table X-1 lists a number of the major pesticide compounds, classified by subcategories and defined in this document, i.e., organic pesticide chemicals, and metallo-organic pesticide chemicals. In addition, some compounds, listed as non-categorized pesticides in Table X-1, have active groups which do not allow classification in the above-mentioned subcategories and which are not covered by these guidelines.

Pesticides are alphabetically listed by common name by subcategory along with their chemical name as defined by U.S.E.P.A. Report 600/9-76-012, Analytical Reference Standards and Supplemental Data for Pesticides and Other Organic Compounds, Research Triangle Park, N.C. 27711. These listings are representative in nature and are not intended to be all inclusive or to exclude compounds not listed. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

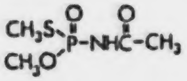
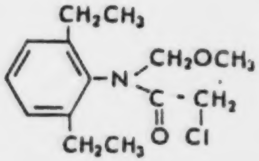
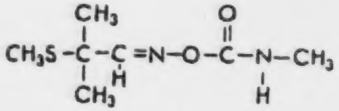
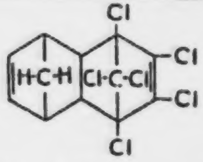
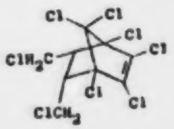
	Common Name	Chemical Name	Structure
1	Acephate (Orthene)	O,S-Dimethly acetylphosphoramidothioate	
2	Alachlor (Lasso)	2-Chloro-2',6'-diethyl-N-(methoxymethyl) acetanilide	
3	Aldicarb (Temik)	2-Methyl-2-(methylthio)-propionaldehyde-O-(methylcarbomoyl) oxime	 $CH_3S-C(CH_3)_2-CH=N-O-C(=O)-NH-CH_3$
4	Aldrin	1,2,3,4,10,10-Hexachloro-1,4,4a,5,8,8a-hexahydro-1,4-endo-exo-5,8-dimethanonaphthalene	
5	Alodan (Hoechstz)	5,6-Bis(chloromethyl)-1,2,3,4,7,7-hexachlorobicyclo [2.2,1] hept-2-ene	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

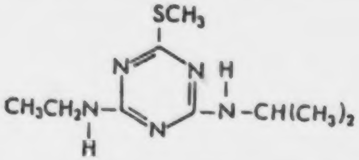
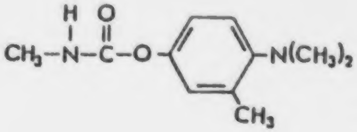
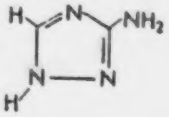
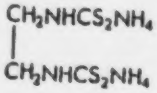
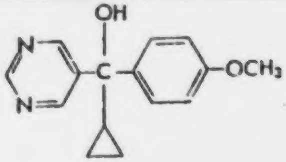
	Common Name	Chemical Name	Structure
6	Ametryn (Evik)	2-(Ethylamino)-4-(isopropylamino)-6-(methylthio)-s-triazine	
7	Aminocarb (Matacil)	4-Dimethylamino-m-tolyl methylcarbamate	
8	Amitrole (Cytrol)	3-Amino-1,2,4-triazole	
9	Amobam (Chemo-O-Bam)	Diammonium ethylenebisdithiocarbamate	 $CH_2NHCS_2NH_4$ – $CH_2NHCS_2NH_4$
10	Ancymidol (A-Rest)	a-Cyclopropyl-a-(p-methoxyphenyl)-5-pyrimidinemethanol	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

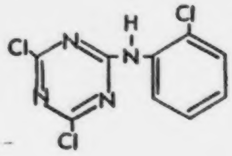
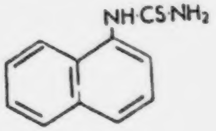
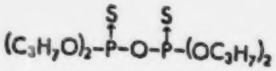
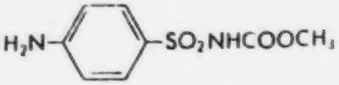
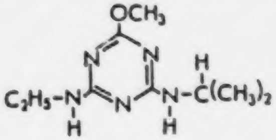
	Common Name	Chemical Name	Structure
11	Anilazine (Dyrene)	2,4-Dichloro-6-(o-chloroanilino)-s-triazine	
12	Antu	1-(1-Naphthyl)-2-thiourea	
13	Aspon	0,0,0,0-Tetrapropyl dithiopyrophosphate	 $(C_3H_7O)_2-\overset{S}{\overset{\uparrow}{P}}-O-\overset{S}{\overset{\uparrow}{P}}-(OC_3H_7)_2$
14	Asulum (Asulox)	Methyl (4-amino benzenesulfonyl)carbamate	
15	Atraton (Gesatamin)	2-(Ethylamino)-4-(isopropylamino)-6-methoxy-s-triazine	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

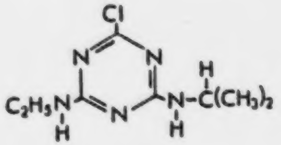
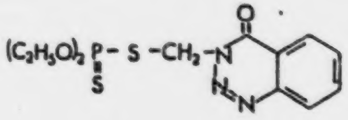
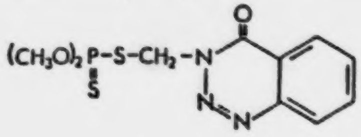
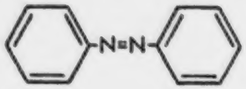
	Common Name	Chemical Name	Structure
16	Atrazine (Aatrex)	2-chloro-4-(ethylamino)-6 (isopropylamino)-s-triazine	
17	Azinphos Ethyl (Ethyl Guthion)	0,0-Diethyl S-[4-oxo-1,2,3-benzotriazin-3 (4H)-yl]methyl]-phosphorodithioate	
18	Azinphos Methyl (Guthion)	0,0-Dimethyl S-[4-oxo-1,2,3-benzotriazin-3 (4H)-yl]methyl]-phosphorodithioate	
19	Azobenzene	Diphenyl diimide	
20	Bandane	Polychlor-tetrahydromethanoindene	Indeterminate. A technical mixture of numerous compounds.

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

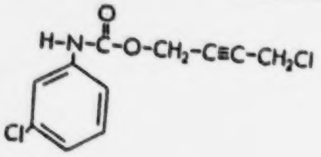
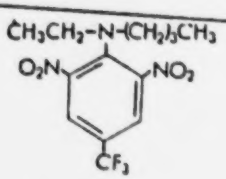
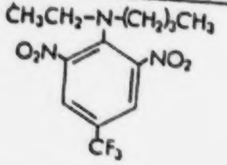
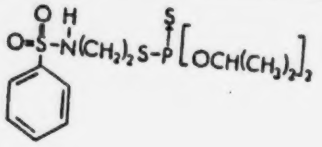
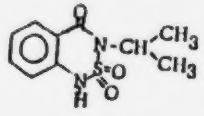
	Common Name	Chemical Name	Structure
21	Barban (Carbyne)	4-Chloro-2-Butynyl-m-chlorocarbanilate	
22	Benefin (Balan)	N-Butyl-N-ethyl-a,a,a-trifluoro-2,6-dinitro-p-toluidine	
23	Benfluralin (Balan, Benefin, Bethrodine, Quilan, Binnell)	N-butyl-N-ethyl-2,6-dinitro-4-trifluoro-methylaniline	
24	Bensulide (Prefar)	S-(O,O-Diisopropyl phosphorodithioate)ester of N-(2-mercaptoethyl)benzenesulfonamide	
25	Bentazon (Basagran)	3-Isopropyl-1H-2,1,3-benzothiadiazin-(4) 3H-one 2, 2-dioxide	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY
SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

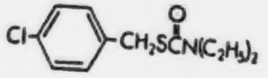
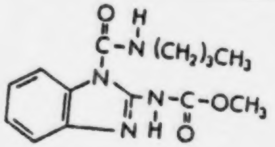
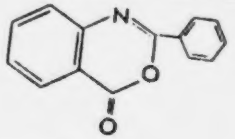
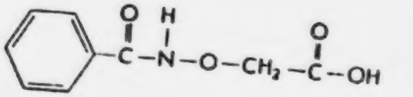
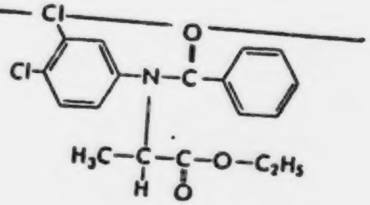
	Common Name	Chemical Name	Structure
26	Benthiocarb (Bolero)	S-(4-Chlorobenzyl)N,N-diethylthiolcarbamate	
27	Benomyl (Benlate)	Methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate	
28	Bentranil	2-Phenyl-3,1-benzoxazinone-(4)	
29	Benzadox (Topcide)	(Benzamidooxy) acetic acid	
30	Benzoylprop Ethyl (Suffic)	Ethyl N-benzoyl-N-(3,4-dichlorophenyl)-2-aminopropionate	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

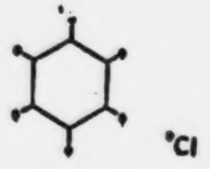
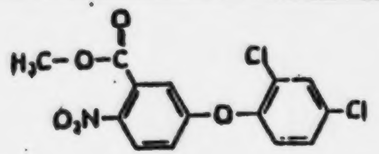
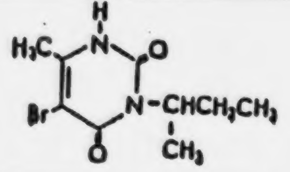
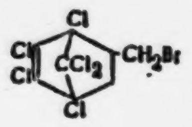
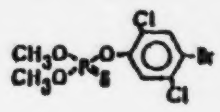
	Common Name	Chemical Name	Structure
31	BHC and related Isomers	Isomers of Hexachlorocyclohexane	
32	Bifenox (Modown)	Methyl 5-(2,4-dichlorophenoxy)-2-nitrobenzoate	 H₃C–O–C O₂N– O Cl –Cl
33	Bromacil (Hyvar)	5-Bromo-3-sec-butyl-6-methyluracil	 H H₃C N O N-CHCH₂CH₃ CH₃ Br O
34	Bromocyclen (Bromodan, Alugan)	5-bromomethyl-1,2,3,4,7,7,-hexachloro-2-norbornene	 Cl Cl Cl CCl₂ CH₂Br Cl
35	Bromophos (Brofene)	O-(4-Bromo-2,5-dichlorophenyl)O,O-dimethyl phosphorothioate	 CH₃O CH₃O P S O Cl Br Cl

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

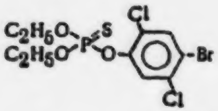
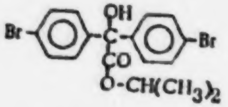
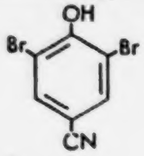
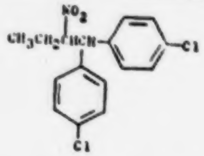
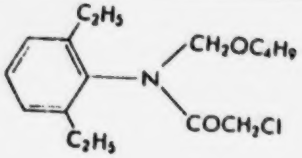
	Common Name	Chemical Name	Structure
36	Bromophos Ethyl (Nexagan)	o-(4-Bromo-2,5-dichlorophenyl)0,0-diethyl phosphorothioate	
37	Bromopropylate	isopropyl 4,4'dibromobenzilate	
38	Bromoxynil (Brominal)	3,5-Dibromo-4-hydroxybenzonitrile	
39	Bulan	1,1'-(2-Nitrobutylidene) bis [4=chlorobenzene]	
40	Butachlor (Machete)	2-Chloro-2',6'-diethyl-N-(butoxymethyl) acetanilide	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

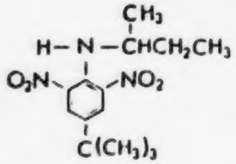
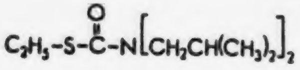
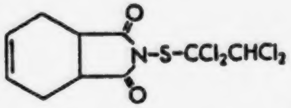
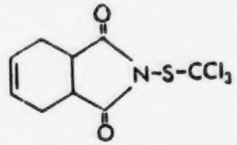
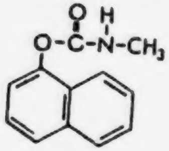
	Common Name	Chemical Name	Structure
41	Butralin (Amex 820)	4-(1,1-Dimethylethyl)-N-(1-methyl propyl)-2,6-dinitronbenzeneamine	
42	Butylate (Sutan)	S-Ethyl N,N-diisobutylthiocarbamate	 $C_2H_5-S-\overset{O}{\overset{\|}{C}}-N[CH_2CH(CH_3)_2]_2$
43	Captafol (Difolaton)	cis-N-[(1,1,2,2-Tetrachloroethyl) thio]-4-cyclohexene-1,2-dicarboximide	
44	Captan	N-[(Trichloromethyl)thio]-4-cyclohexene-1,2-dicarboximide	
45	Carbaryl (Sevin)	1-Naphthyl N-methylcarbamate	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

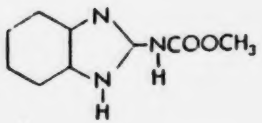
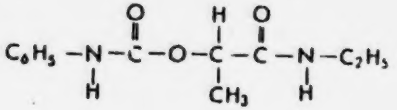
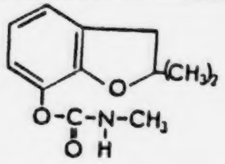
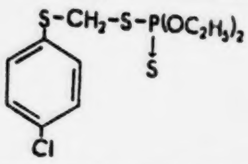
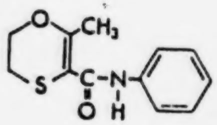
	Common Name	Chemical Name	Structure
46	Carbendazim (Derosal)	2-(Methoxycarbonylamino)-benzimidazol	
47	Carbetamide (Legurame)	N-Phenyl-1-(ethylcarbamoyl)-ethylcarbamate, D isomer	 $C_6H_5-\underset{H}{N}-\overset{O}{\overset{\parallel}{C}}-O-\overset{H}{\underset{CH_3}{C}}-\overset{O}{\overset{\parallel}{C}}-\underset{H}{N}-C_2H_5$
48	Carbofuran (Furadan)	2,3-Dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate	
49	Carbophenothion (Trithion)	S-[(p-Chlorophenylthio)-methyl]O,O-diethyl phosphorodithioate	
50	Carboxin (Vitavax)	5,6-Dihydro-2-methyl-1,4-oxathiin-3-carboxanilide	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

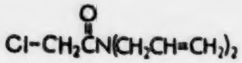
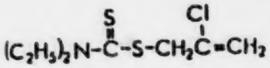
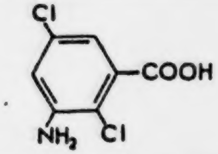
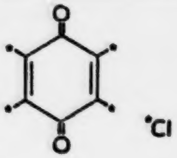
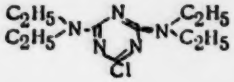
	Common Name	Chemical Name	Structure
51	CDAA (Randox)	N,N-Diallyl-2-chloroacetamide	 $Cl-CH_2\overset{O}{\overset{\|}{C}}N(CH_2CH=CH_2)_2$
52	CDEC (Sulfallate)	2-Chloroallyl diethyldithiocarbamate	 $(C_2H_5)_2N-\overset{S}{\overset{\|}{C}}-S-CH_2\overset{Cl}{\overset{\|}{C}}=CH_2$
53	Chloramben (Amiben)	3-Amino-2,5-dichlorobenzoic acid	
54	Chloranil (Spergon)	2,3,5,6-Tetrachloro-1,4-benzoquinone	
55	Chlorazine	2-chloro-4,6-bis(diethylamino)-1,3,5-triazine	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1--ORGANIC PESTICIDES CHEMICALS

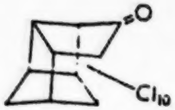
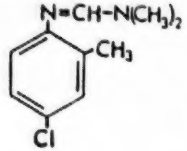
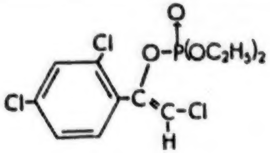
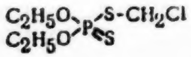
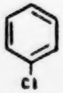
	Common Name	Chemical Name	Structure
56	Chlordecone (Kepone)	Decachloro-octahydro-1,3, 4-metheno-2H-cyclobuta[cd]-pentalen-2-one	
57	Chlordimeform (Chlorphenamidine)	N'-(4-Chloro-o-tolyl)-N, N-dimethylformamidine	
58	Chlorfenvinphos (Supona)	2-Chloro-1-(2,4-dichlorophenyl)vinyl diethyl phosphate	
59	Chlormephos (MC 2188)	S-Chloromethyl o,o-diethyl phosphorothiolothionate	
60	Chlorobenzene	Monochlorobenzene	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

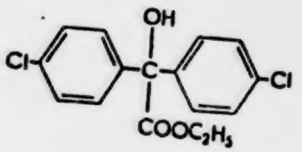
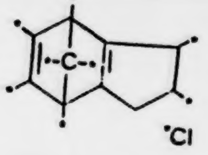
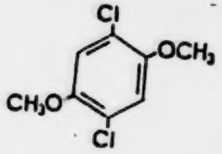
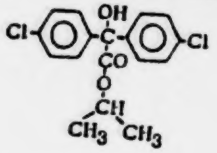
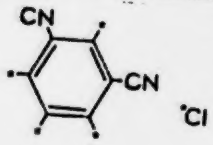
	Common Name	Chemical Name	Structure
61	Chlorobenzilate (Acarben)	Ethyl 4,4'-dichlorobenzilate	
62	Chlorodane (Tech.) and Components	1,2,4,5,6,7,8,8-Octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene	
63	Chloroneb (Demosan)	1,4-Dichloro-2,5-dimethoxybenzene	
64	Chloropropylate	isopropyl 4,4'-dichlorobenzilate	
65	Chlorothalonil (Daconil 2787)	2,4,5,6-Tetrachloroisophthalonitrile	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

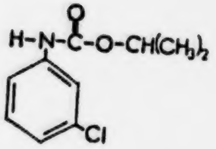
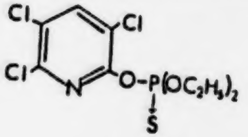
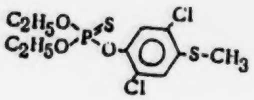
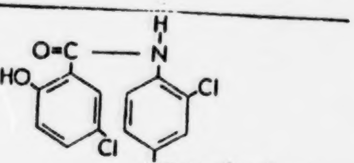
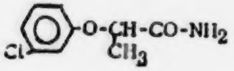
	Common Name	Chemical Name	Structure
66	Chlorpropham (CIPC)	Isopropyl N-(3-chlorophenyl) carbamate	
67	Chlorpyrifos (Dursban)	o,o-Diethyl o-(3,5,6-trichloro-2-pyridyl) phosphorothioate	
68	Chlorthiophos (CMS 2957)	o,o-Diethyl 0-2,4,5-Dichloro-(methylthio) phenyl thionophosphate	
69	Clonitralid (Bayluscide)	2',5-Dichloro-4'-nitrosalicylanilide ethanolamine	
70	4 - CPA	4-chlorophenoxyacetic acid	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

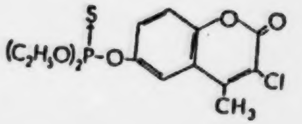
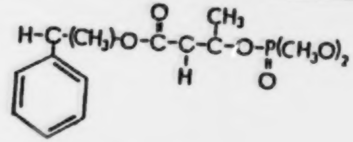
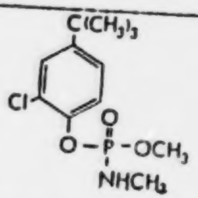
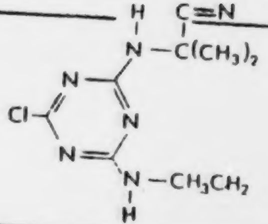
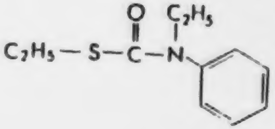
	Common Name	Chemical Name	Structure
71	Coumaphos (Co-Ral)	o-(3-Chloro-4-methyl-2-oxo-2H-1-benzopyran-7-yl) 0,0-diethyl phosphorothioate	
72	Crotoxyphos (Ciodrin)	a-Methylbenzyl 3-hydroxy-crotonate dimethyl phosphate	
73	Crufomate (Ruelene)	0-(4-tert-Butyl-2-chlorophenyl) 0-methyl N-methyl phosphoroamidate	
74	Cyanazine (Bladex)	2-[(4-Chloro-6-(ethylamino)-s-triazin-2-yl) amino]-2-methlypropionitrite	
75	Cycloate (Ro-Neet)	S-Ethyl ethylcyclohexylthio-carbamate	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

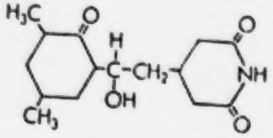
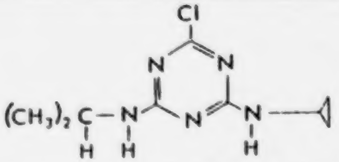
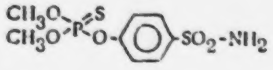
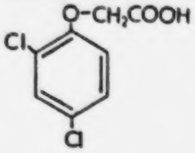
	Common Name	Chemical Name	Structure
76	Cycloheximide (Actidione)	3[2-(3,5-Dimethyl-2-oxocyclohexyl)-2-hydroxyethyl]glutarimide	
77	Cyprazine (Outfox)	2-Chloro-4-(cyclopropylamino)-6-(isopropylamino)-s-triazine	
78	Cythioate (Proban)	o,O-Dimethyl O-p-sulfamoylphenyl phosphorothioate	
79	2,4-D and its derivatives	2,4-Dichlorophenoxyacetic acid, esters, and salts	
80	Dalapon (Dowpon) and its salts	2,2-Dichloropropionic acid	CH_3CCl_2COOH

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

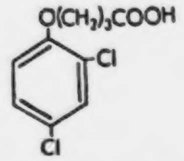
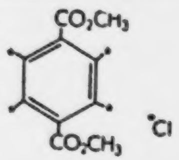
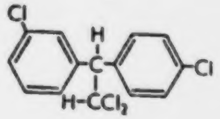
	Common Name	Chemical Name	Structure
81	2,4-DB, Acid and Esters	4-(2,4-Dichlorophenoxy) butyric acid, and esters	
82	DBCP (Dibromochloropropane)	1,2-Dibromo-3-chloropropane and related halogenated C3 hydrocarbons	$CH_2Br\text{-}CHBr\text{-}CH_2Cl$
83	DCPA (Dacthal)	Dimethyl 2,3,5,6-tetrachloroterephthalate	
84	DD (Nemex, Vidden)	Tech. mixture of 1,3-dichloropropene and 1,2-dichloropropene	$CH_2Cl\text{-}CH{=}CHCl$ $CH_2Cl\text{-}CHCl\text{-}CH_3$
85	DDD, Mixed, Tech. (TDE, Rhothane) and Metabolites	2,2-Bis(chloropheny)-1, 1-dichloroethane and related compounds	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

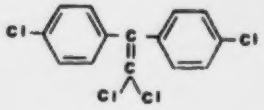
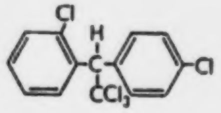
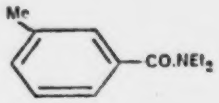
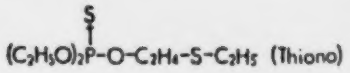
	Common Name	Chemical Name	Structure
86	DDE	1,1-dichloro-2,2-di(chlorophenyl) ethene	
87	DDT, Mixed, (Tech.) and Metabolites	Dichloro diphenyl trichloroethane (mixt. of metabolites of ca. 80% p,p' and 20% o,p')	
88	DEET	NN-diethyl-m-toluamide	
89	DEF	S,S,S-Tributyl phosphorotrithioate	$(CH_3CH_2CH_2CH_2S)_3P{=}O$
90	Demeton-o (Systox-o) (Thiono)	0,0-Diethyl o-2-[(ethylthioethyl]phosphorothioate	 $(C_2H_5O)_2\overset{S}{\overset{\uparrow}{P}}-O-C_2H_4-S-C_2H_5$ (Thiono)

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PFSTICIDES CHEMICALS

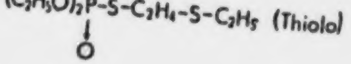
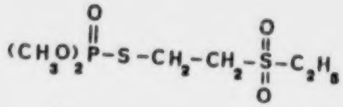
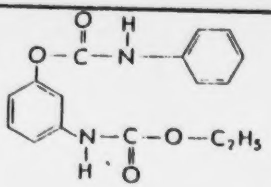
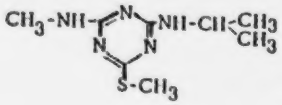
	Common Name	Chemical Name	Structure
91	Demeton-S (Systox-S) (Thiolo)	o,o-Diethyl S-2-[(ethlythio)-ethyl]phosphorothioate	 $(C_2H_5O)_2\underset{\underset{O}{\downarrow}}{P}-S-C_2H_4-S-C_2H_5$ (Thiolo)
92	Demeton-S-Methyl	5-2-ethlythioethyl-0,0-dimethly phosphorothioate	$(CH_3O)_2P-S-CH_2CH_2-S-C_2H_5$
93	Demeton-S-Methylsulfone	5-2-ethylsulphonylethyl 0,0-dimethyl phosphorothioate	 $(CH_3O)_2\overset{O}{\overset{\|}{P}}-S-CH_2-CH_2-\overset{O}{\overset{\|}{\underset{\underset{O}{\|}}{S}}}-C_2H_5$
94	Desmedipham (Betanex)	Ethyl m-hydroxycarbanilate carbanilate (ester)	
95	Desmetryne (Semeron)	2-Methylthio-4-methylamino-6-isopropylamino-s-triazine	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

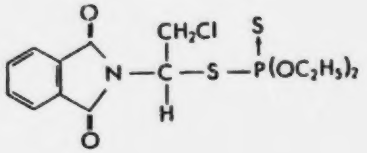
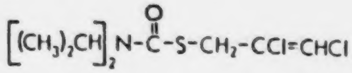
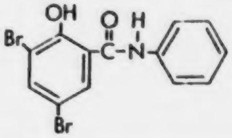
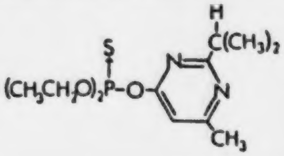
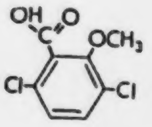
	Common Name	Chemical Name	Structure
96	Dialifor (Torak)	s-(2-Chloro-1-phthalimido-ethyl)0,0-diethyl phosphorodithioate	
97	Diallate (Avadex)	S-(2,3-Dichloroallyl)diisopropylthiocarbamate	 $[(CH_3)_2CH]_2N-\overset{O}{\overset{\|}{C}}-S-CH_2-CCl=CHCl$
98	Diaphene (Bromsalans)	3,4,5-Tribromosalicyanilide,4,5-dibromosalicylanilide and other brominated salicylanilides	
99	Diazinon (Spectracide)	o,o-Diethyl o-(2-isopropyl-6-methyl-4-pyrimidinyl) phosphorothioate	
100	Dicamba (Banvel D)	2-Methoxy-3,6-dichlorobenzoic acid	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

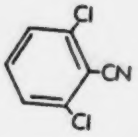
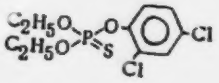
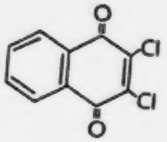
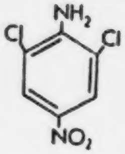
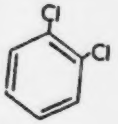
	Common Name	Chemical Name	Structure
101	Dichlobenil (Casoron)	2,6-Dichlorobenzonitrile	
102	Dichlofenthion (VC-13)	o-2,4-Dichlorophenyl o,o-diethyl phosphorothioate	
103	Dichlone (Phygon XL)	2,3-Dichloro-1,4-naphthoquinone	
104	Dichloran (Botran)	2,6-Dichloro-4-nitroaniline	
105	Dichlorbenzene, ortho (ODB)	1,2-Dichlorobenzene	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

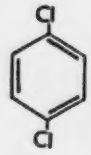
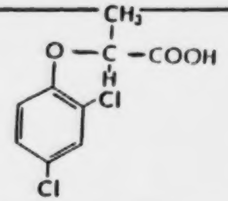
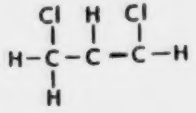
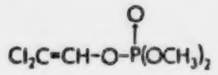
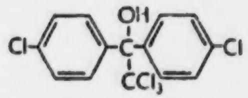
	Common Name	Chemical Name	Structure
106	Dichlorobenzene, Para (PDB)	1,4-Dichlorobenzene	
107	Dichloroprop (2,4-DP)	2-(2,4-Dichlorophenoxy)-propionic acid	
108	Dichloropropene (Telone)	1,3-Dichloropropene	 $\mathrm{H{-}\underset{H}{\overset{Cl}{C}}{-}\overset{H}{C}{-}\overset{Cl}{C}{-}H}$
109	Dichlorvós (DDVP)	2,2-Dichlorovinyl dimethyl phosphate	 $\mathrm{Cl_2C{=}CH{-}O{-}\overset{O}{P}(OCH_3)_2}$
110	Dicofol (kelthane)	1,1-Bis (p-chlorophenyl)-2, 2,2-trichloroethanol	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

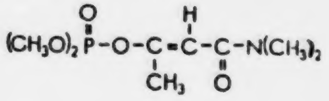
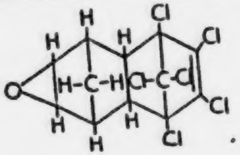
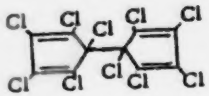
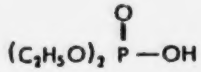
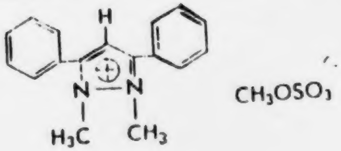
Common Name	Chemical Name	Structure
111. Dicrotophos (Bidrin)	3-Hyroxy-N,N-dimethyl-cis crotonamide dimethyl phosphate	 $(CH_3O)_2\overset{O}{\overset{\|}{P}}-O-\underset{CH_3}{C}=\overset{H}{C}-\underset{O}{\underset{\|}{C}}-N(CH_3)_2$
112 Dieldrin (HEOD)	1,2,3,4,10,10-Hexachloro-exo-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo, exo-5,8-dimethanonaphthalene	
113 Dienochlor (Pentac)	Perchlorobi (cyclopenta-2,4-dien-1-yl)	
114 Diethyl Phosphate (DEP)	o,o-Diethyl phosphate	 $(C_2H_5O)_2\overset{O}{\overset{\|}{P}}-OH$
115 Difenzoquat (Avenge)	1,2-Dimethyl-3,5-diphenyl-1H-pyrazolium methyl sulfate	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

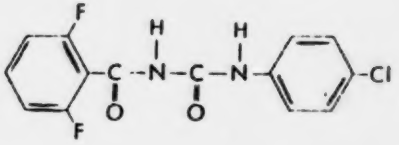
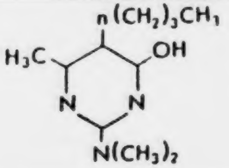
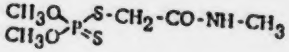
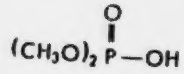
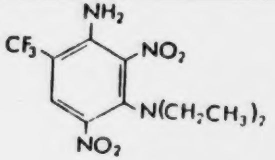
	Common Name	Chemical Name	Structure
116	Diflubenzuron (Th-6040,Dimilin)	1-(4-Chlorophenyl)-3-(2,6-difluorobenzoyl)urea	
117	Dimethirimol (Milcurb)	5-n-Butyl-2-dimethylamino-4-hydroxy-6-methylpyrimidine	
118	Dimethoate (Cygon)	0,0-Dimethyl S-(N-methylcarbamoylmethyl) phosphorodithioate	 $\begin{matrix}CH_3O\\CH_3O\end{matrix}\!>\!P{=}S\,\text{-}S\text{-}CH_2\text{-}CO\text{-}NH\text{-}CH_3$
119	Dimethyl Phosphate (DMP)	o,o-Dimethyl phosphate	 $(CH_3O)_2\overset{\overset{O}{\|}}{P}—OH$
120	Dinitramine (Cobex)	N4,N4-Diethly-a,a,a-trifluoro-3,5-dinitro toluene-2,4-diamine	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

i

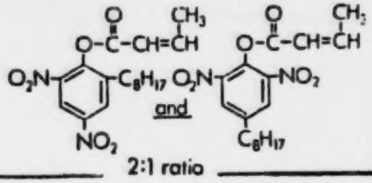
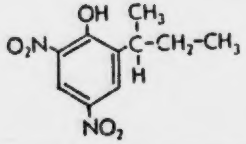
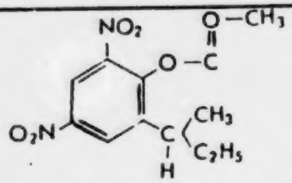
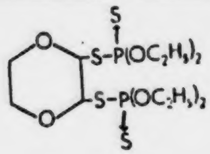
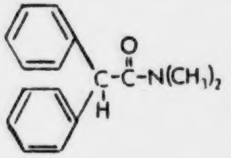
	Common Name	Chemical Name	Structure
121	Dinocap (Karathane)	2-(1-Methylheptyl)-4,6-dinitrophenyl crotonate	
122	Dinoseb (DNBP)	2-(sec-Butyl)-4,6-dinitrophenol	
123	Dinoseb Acetate (Aretit)	2-(sec-Butyl)-4,6-dinitrophenyl acetate	
124	Dioxathion (Delnav)	s,s'-p-Dioxane-2,3-diyl o,o-diethyl phosphorodithioate (cis and trans isomers)	
125	Diphenamid (Enide)	N,N-Dimethyl-2,2-diphenylacetamide	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

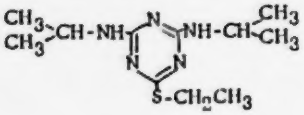
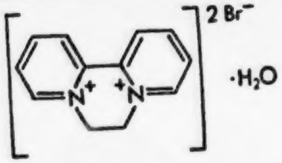
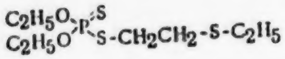
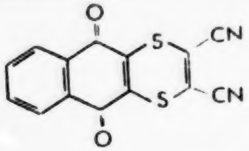
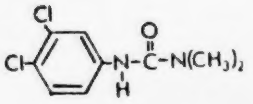
	Common Name	Chemical Name	Structure
126	Dipropetryn (Sancap)	2-(ethylthio)-4,6-bis-(isopropylamino)-1,3,4-triazine	
127	Diquat Dibromide	6,7-Dihydrodipyrido[1,2-a:2',1'-c]pyrazidiinium dibromide, monohydrate	
128	Disulfoton (Di-Syston)	0,0-Diethyl S-[2-(ethylthio)-ethyl]phosphorodithioate	
129	Dithianon	2,3-Dicarbonitrile-1, 4-dithiaanthraquinone	
130	Diuron	3-(3.4-Dichlorophenyl)-1-dimethylurea	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

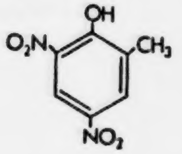
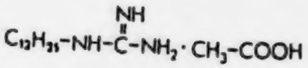
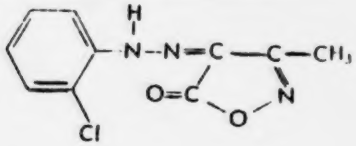
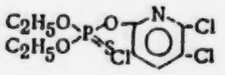
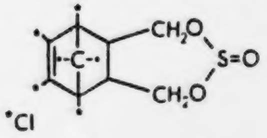
	Common Name	Chemical Name	Structure
131	DNOC	4,6-Dinitro-o-cresol	
132	Dodine (Carpene)	n-Dodecylguanidine acetate	 $C_{12}H_{25}-NH-\overset{\overset{NH}{\Vert}}{C}-NH_2 \cdot CH_3-COOH$
133	Drazoxolon (Ganocide)	4-(2-Chlorophenylhydrazono)-3-methyl-5-isoxazolone	
134	Dursban	o,o-Diethyl o-(3,4,6-Tri-chloro-2-pyridyl) phosphorothioate	
135	Endosulfan (Thiodan) and Isomers	6,7,8,9,10,10-Hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodioxathiepon 3-oxide	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

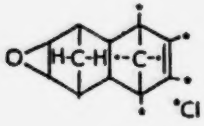
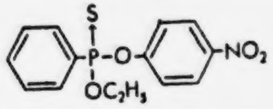
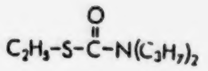
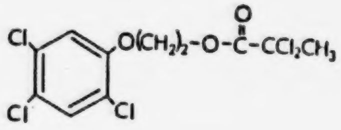
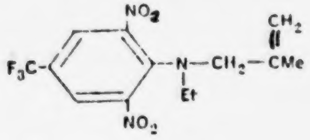
	Common Name	Chemical Name	Structure
136	Endrin	1,2,3,4,10,10-Hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo,endo-5,8-dimethanonaphthalene	
137	EPN	O-Ethyl O-p-nitrophenyl phenylphosphonothioate	
138	EPTC (Eptam)	S-Ethyl dipropylthiocarbamate	 $C_2H_5\text{-}S\text{-}\overset{O}{\overset{\parallel}{C}}\text{-}N(C_3H_7)_2$
139	Erbon (Baron)	2-(2,4,5-Trichlorophenoxy) ethyl 2,2-dichloropropionate	
140	Ethalfluralin	N-ethyl-N-(2-methy)	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

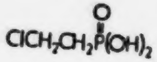
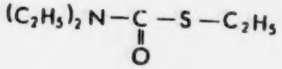
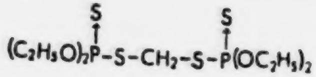
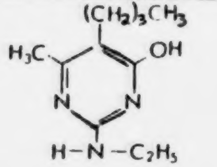
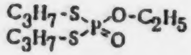
	Common Name	Chemical Name	Structure
141	Ethephon (Cepha)	(2-Chloroethyl)phosphonic acid	 $ClCH_2CH_2\overset{O}{\overset{\|}{P}}(OH)_2$
142	Ethiolate (Prefox)	S-Ethyl diethylthiocarbamate	 $(C_2H_5)_2N-\underset{\underset{O}{\|}}{C}-S-C_2H_5$
143	Ethion	0,0,0',0-Tetraethyl S,S'-methylene bisphosphorodithioate	 $(C_2H_5O)_2\overset{S}{\overset{\uparrow}{P}}-S-CH_2-S-\overset{S}{\overset{\uparrow}{P}}(OC_2H_5)_2$
144	Ethirimol (Milstem)	5-Butyl-2-(ethlyamino)-6-hydroxy-4-methylpyrimidine	
145	Ethoprop (Mocap)	0-Ethyl S,S,-dipropyl phosphorodithioate	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

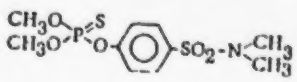
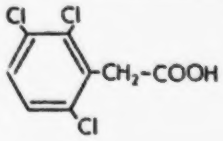
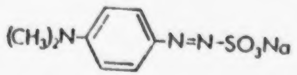
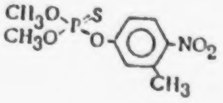
	Common Name	Chemical Name	Structure
146	Ethylene Dibromide (Bromofume, Dowfume W-85, Soilbrom-85, EDB, Nephis)	1,2-dibromoethane	CH_2Br-CH_2Br
147	Famphur	O-[p-(dimethylsulfamoyl) phenyl]O,O-dimethyl phosphorothioate	
148	Fenac	2,3,6-Trichlorophenyl-acetic acid	
149	Fenaminosulf (Dexon)	p-(Dimethylamino)benzenediazo sodium sulfonate	
150	Fenitrothion (Sumithion)	O,O-Dimethyl O-(4-nitro-m-tollyl)phosphorothioate	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

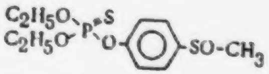
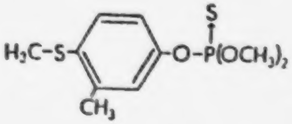
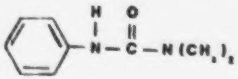
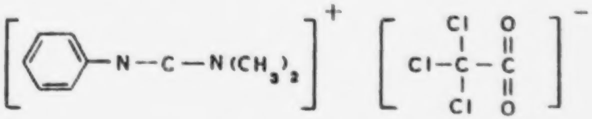
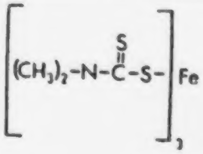
	Common Name	Chemical Name	Structure
151	Fensulfothion (Dasanit)	0,0-Diethyl 0-[p-(methylsulfinyl)phenyl] phosphorothioate	
152	Fenthion (Baytex)	0,0-Dimethyl 0-[4-(methylthio)-m-tolyl] phosphorothioate	
153	Fenuron	1,1-dimethyl-3-phenylurea	
154	Fenuron-TCA (Urab)	1,1-dimethyl-3-phenyluronium trichloroacetate	
155	Ferbam	Ferric dimethyldithiocarbamate	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

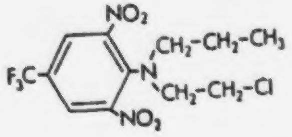
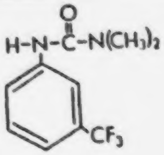
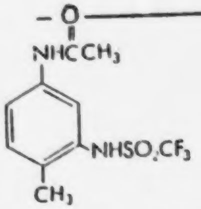
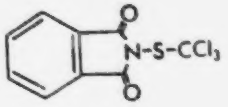
Common Name	Chemical Name	Structure
156 Fluchloralin (Basalin)	N-Propyl-N-(2-chloroethyl)-a,a,a-trifluoro-2,6-dinitro-p-toluidine	
157 Fluometuron (Cotoran)	1,1-Dimethly-3-(a,a,a-trifluoro-m-tolyl)urea	
158 Fluoridamid (Sustar 2-S)	N-4-Methyl-3-[(1,1,1-trifluoromethyl)sulfonyl] amino]phenyl]acetamide	
159 Folex (Merphos)	Tributyl Phosphorotrithioite	$(C_4H_9S)_3P$
160 Folpet (Phaltan)	N-(Trichloromethylthio)-phthalimide	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

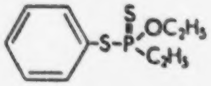
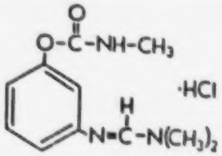
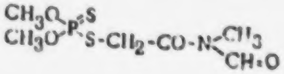
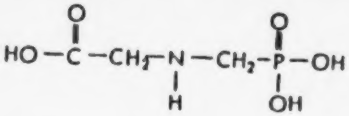
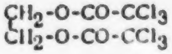
	Common Name	Chemical Name	Structure
161	Fonofos (Dyfonate)	O-Ethyl S-phenyl ethylphosphonodithioate	
162	Formetanate Hydrochloride (Carzol SP)	m[[(Dimethlyamino)methylene]-amino]phenyl methylcarbamate hydrochloride	
163	Formothion (Anthio)	o,o-Dimethyl S-(N-methyl-N-formylcarbamoyl-methyl)-phosphorodithioate	
164	Glyphosate (Roundup)	N-(Phosphonomethyl)glycine	
165	Glytac (EGT)	ethyleneglycolbis (trichloroacetate)	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

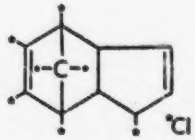
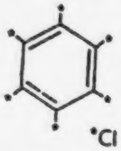
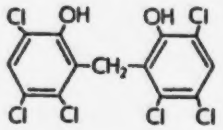
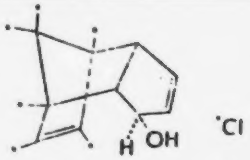
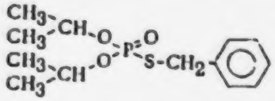
	Common Name	Chemical Name	Structure
166	Heptachlor	1,4,5,6,7,8,8-Heptachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene	
167	Hexachlorobenzene (HCB)	Hexachlorobenzene	
168	Hexachlorphene (Nabac)	2-2'-Methylene bis(3,4,6-trichlorophenol)	
169	1-Hydroxychlordene	1-exo, Hydroxy-4,5,6,7,8,8-hexachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene	
170	IBP (Kitazin)	0,0-Diisopropyl S-benzyl thiophosphate	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

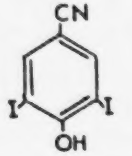
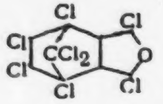
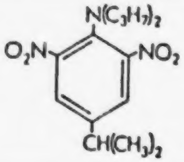
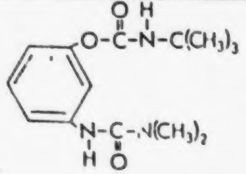
	Common Name	Chemical Name	Structure
171	Ioxynil (Actril)	4-Hydroxy-3,5-Diiodo-benzonitrile	
172	Isobenzan (Telodrin)	1,3,4,5,6,7,8,8-Octachloro-1,3,3a,4,7,7a-hexahydro-4,7-methanoisobenzofuran	
173	Isodrin	1,2,3,4,10,10-Hexachloro-1,4,4a,5,8,8a-hexahydro-endo,endo-1,4:5,8-dimethanonaphthalene	See Aldrin which is the endo-exo isomer
174	Isopropalin (Paarlan)	2,6-Dinitro-N,N-dipropy-loumidine	
175	Karbutilate (Tandex)	m-(3,3-dimethylureido)phenyl tert-butylcarbamate	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

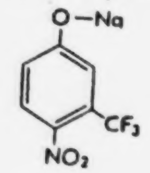
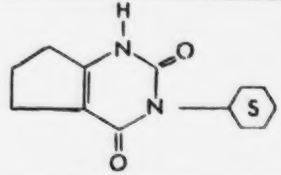
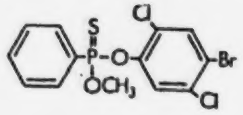
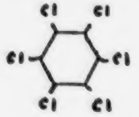
	Common Name	Chemical Name	Structure
176	Lamprecide (TFN)	3-Trifluoromethyl-4-nitrophenol, sodium salt	
177	Lenacil (Venzar)	3-Cyclohexyl-6,7-dihydro-1H-cyclopentapyrimidine-2,4(3H,5H)-dione	
178	Leptophos (phosvel)	O-(4-Bromo-2,5-dichlorophenyl)O-methyl phenylphosphonothioate	
179	Lethane 384	b-Butoxy-B'-thiocyanodiethyl ether	$C_4H_9O(CH_2)_2-O-(CH_2)_2-S-CN$
180	Lindane	12,22,3B,42,52,6B-Hexachlorocyclohexane	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

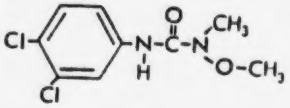
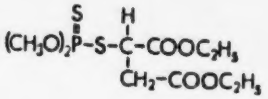
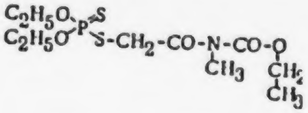
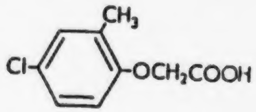
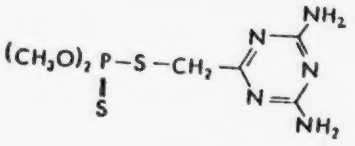
	Common Name	Chemical Name	Structure
181	Linuron (Lorox)	3-(3,4-Dichlorophenyl)-1-methoxy-1-methylurea	
182	Malathion	Diethyl mercaptosuccinate, s-ester with 0,0-dimethyl phosphorodithioate	 $(CH_3O)_2\overset{S}{P}-S-\underset{CH_2-COOC_2H_5}{\overset{H}{C}}-COOC_2H_5$
183	Mecarbam (MC-474)	S-[N-Ethoxycarbonyl-N-methylcarbamoylmethyl]0,0-diethly phosphorodithioate	 $(C_2H_5O)_2\overset{S}{P}-S-CH_2-CO-\underset{CH_3}{N}-CO-\underset{CH_2CH_3}{O}$
184	MCPA, MCPB, MCPP, Acids and esters	(4-Chloro-2-methylphenoxy)-acetic acids and esters	
185	Menazon (Azidithion)	S-[(4,6-Diamino-1,3,5-triazin-2-yl)methyl]0,0-dimethyl phosphorodithioate	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

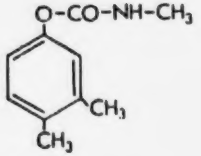
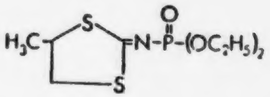
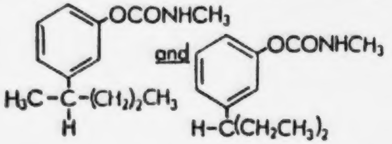
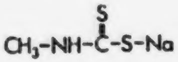
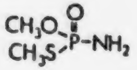
	Common Name	Chemical Name	Structure
186	Meobal	3,4-Xylyl methylcarbamate	
187	Mephosfolan (Cytrolane)	P,P-Diethyl cyclic propylene ester of phosphonodithioimidocarbonic acid	
188	Metalkamate (Bux)	Mixture of m-(1-ethylpropyl)-phenyl methylcarbamate and m-(1-methylbutyl) phenyl methylcarbamate (ratio of 1:3)	
189	Metham (SMDC)	Sodium N-methyldithiocarbamate	 $CH_3-NH-\overset{S}{\overset{\|}{C}}-S-Na$
190	Methamidophos (Monitor)	O-S-Dimethyl phosphoramidothioate	 $(CH_3O)(CH_3S)\overset{O}{\overset{\|}{P}}-NH_2$

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

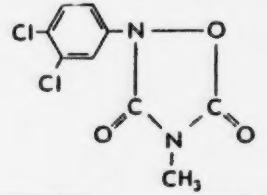
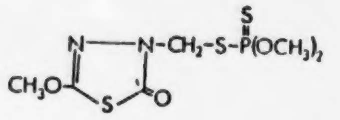
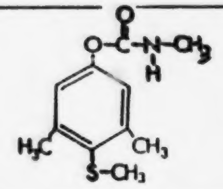
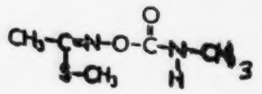
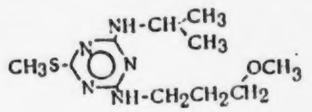
	Common Name	Chemical Name	Structure
191	Methazole (Probe)	2-(3,4-Dichlorophenyl)-4-Methyl-1,2,4-oxadiazolidine-3,4,-dione	
192	Methidathion (Supracide)	S-[(2-methoxy-5-oxo-delta-1,3,4-thiadiazolin-4-yl)-methyl]O,O-dimethly phosphorodithioate	
193	Methiocarb (Mesurol)	4-(Methylthio)-3,5-xylyl N-methylcarbamate	
194	Methomyl (Lannate)	S-Methyl N-[(methylcarbomoyl)-oxy] thioacetimidate	
195	Methoprotryne (Gesaran)	2-Methylthio-4-isopropylamino-6-methoxypropylamino-s-triazine	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

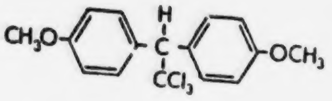
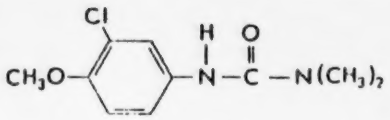
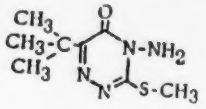
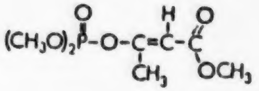
	Common Name	Chemical Name	Structure
196	Methoxychlor (Marlate)	2,2-Bis (p-methoxyphenyl)-1,1,1-trichloroethane	
197	Methyl Bromide	Bromomethane	CH_3Br
198	Metoxuron (Dosanex)	3-(3-Chloro-4-methoxyphenyl)-1,1-dimethylurea	
199	Metribuzin (Sencor)	4-amino-6-tert-butyl-3-(methylthio)-1,2,4,triazine-5-one	
200	Mevinphos (Phosdrin)	Methyl 3-hydroxy-alpha-crotonate, dimethyl phosphate	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

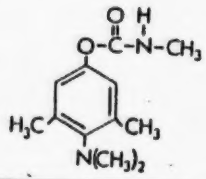
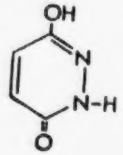
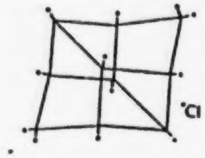
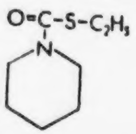
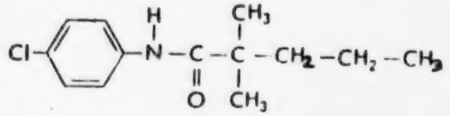
	Common Name	Chemical Name	Structure
201	Mexacarbate (Zectran)	4-Dimethylamino-3,5-xylyl methylcarbamate	
202	MH (maleic Hydrazide)	6-Hydroxy-3-(2H)-pyridazinone	
203	Mirex (Dechlorane)	Dodecachlorooctahydro-1, 3,4-metheno-2H-cyclobuta [cd] pentalene	
204	Molinate (Ordram)	S-Ethyl hexahydro-1H-azepine-1-carbothiate	
205	Monalide (Potablan)	N-(4-Chlorophenyl)-2,2-dimethylpentanamide	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

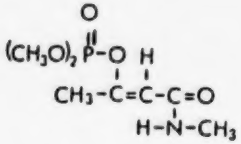
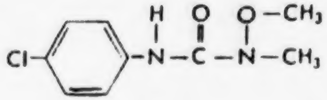
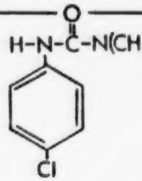
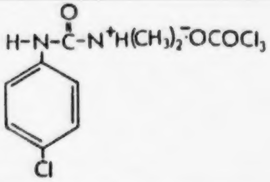
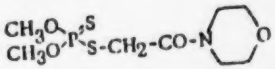
	Common Name	Chemical Name	Structure
206	Monocrotophos (Azodrin)	Dimethyl phosphate of 3-hydroxy-N-methyl-cis-crotonamide	
207	Monolinuron (Aresin)	3-(p-Chlorphenyl)-methoxy-1-methylurea	
208	Monuron	3-(p-Chlorphenyl)-1,1-dimethylurea	
209	Monuron-TCA (Urox)	3-(p-Chlorophenyl)-1,1-dimethylurea trichloroacetate	
210	Morphothion (Ekatin M)	O,O-Dimethly S-(morpholinocarbonylmethyl) phosphorodithioate	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

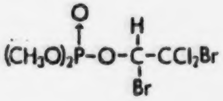
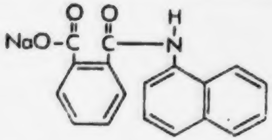
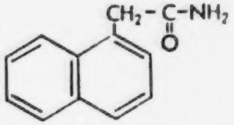
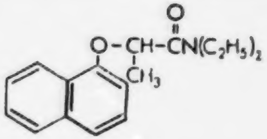
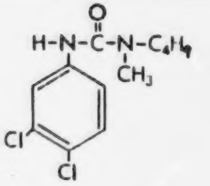
	Common Name	Chemical Name	Structure
211	Naled (Dibrom)	1,2-Dibromo-2,2-dichloroethyl dimethyl phosphate	 $(CH_3O)_2\overset{O}{P}-O-\overset{H}{\underset{Br}{C}}-CCl_2Br$
212	Naptalam, Sodium Salt	Sodium N-1-naphthylphthamate	
213	Naphthalene Acetamide	1-Naphthalene-acetamide	
214	Napropamide (Devrinol)	2-(a-Naphthoxy)-N,N-diethylpropionamide	
215	Neburon	1-(n-Butyl)-3-(3,4-dichlorophenyl)-1-methylurea	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

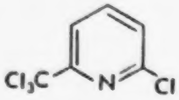
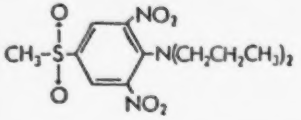
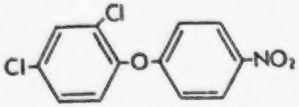
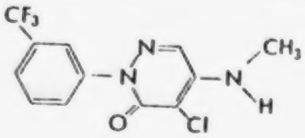
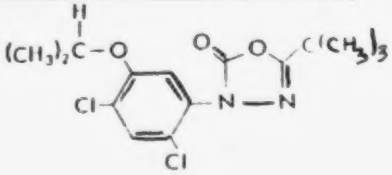
	Common Name	Chemical Name	Structure
216	Nitrapyrin (N-Serve TG)	2-Chloro-6-trichloromethylpyridine (and related chlorinated pyridines)	
217	Nitralin (Planavin)	4-(Methylsulfonyl)-2,6-dinitro-N,N-dipropylaniliane	
218	Nitrofen (TOK)	2,4-Dichlorophenyl-p-nitrophenyl ether	
219	Norflurazon (Evital)	4-Chloro-5-(methylamino)-2-(a,a,a-trifluoro-m-toyl)-2H)-pyridazinone	
220	Oxadiazon (Ronstar)	2-tert-Butyl-4-(2,4-dichloro-5-isopropoxyphenyl) delta-1,3,4-oxadiazolin-5-one	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

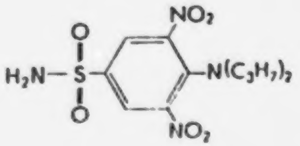
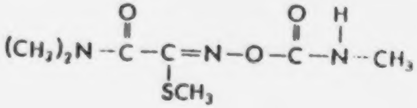
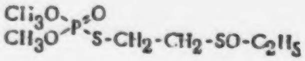
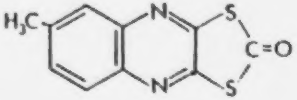
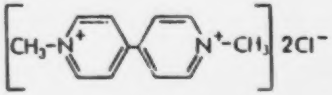
	Common Name	Chemical Name	Structure
221	Oryzalin (Surflan)	3,5-Dinitro-N4,N4-dipropylsulfanilamide	
222	Oxamyl (Vydate)	Methyl N',N'-diomethyl-N-[(methylcarbomoyl) oxy]-1 thiooxamimidate	 $(CH_3)_2N-\overset{O}{\overset{\parallel}{C}}-\underset{SCH_3}{\underset{\mid}{C}}=N-O-\overset{O}{\overset{\parallel}{C}}-\overset{H}{\overset{\mid}{N}}-CH_3$
223	Oxydemeton Methyl	S-[2-(ethylsulfinyl)ethyl-0,0-dimethyl phosphorothioate	
224	Oxythioquinox (Morestan)	6-Methyl-2,3-quinoxalinedithiol cyclic-S, S-dithiocarbonate	
225	Paraquat Dichloride (Gramoxone)	1,1'-Dimethyl-4,4'-bipyridilium dichloride	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

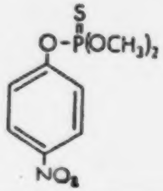
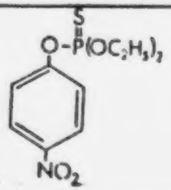
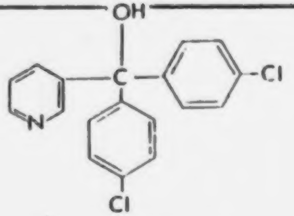
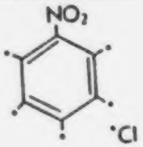
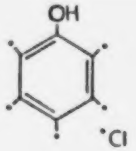
	Common Name	Chemical Name	Structure
226	Parathion Methyl	0,0-Dimethyl 0-p-nitrophenyl phosphorothioate	
227	Parathion Ethyl	0,0-Diethyl-0-p-nitrophenyl phosphorothioate	
228	Parinol (Parnon)	a,a-Bis (p-chlorophenyl)-3-pyridine methanol	
229	PCNB (Quintozene)	Pentachloronitrobenzene	
230	PCP and its salts	2,3,4,5,6-Pentachlorophenol	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1.-ORGANIC PESTICIDES CHEMICALS

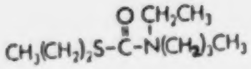
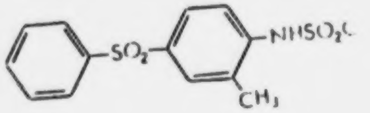
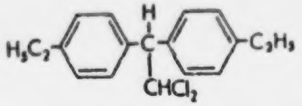
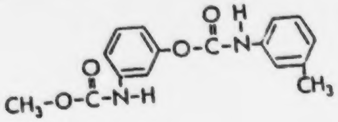
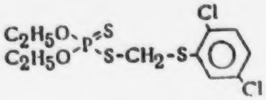
	Common Name	Chemical Name	Structure
231	Pebulate (Tillam)	S-Propyl butylethylthiocarbamate	 $CH_3(CH_2)_2S-\overset{O}{\overset{\|}{C}}-\overset{CH_2CH_3}{\overset{\|}{N}}(CH_2)_3CH_3$
232	Perfluidone (Destun)	1,1,1-Trifluoro-N-[2-methyl-4-(phenylsulfonyl) phenyl] methanesulfonamide	
233	Perthane	1,1-Dichloro-2,2-bis (p-ethylphenyl)ethane	
234	Phenmedipham (Betanal)	Methyl m-hydroxycarbanilate m-methylcarbanilate	
235	Phencapton	O,O-Diethyl-S-(2,5-dichlorophenylthiomethyl) phosphorothiolothionate	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

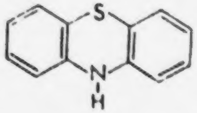
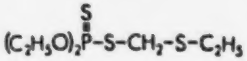
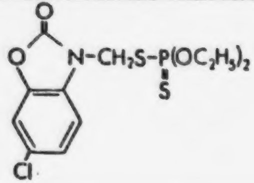
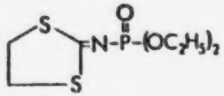
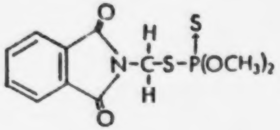
	Common Name	Chemical Name	Structure
236	Phenothiazine	Dibenzo-1,4-thiazine	
237	Phorate (Thimet)	0,0-Diethyl S-[(ethylthio)-methyl]phosphorodithioate	 $(C_2H_5O)_2\overset{S}{\overset{\Vert}{P}}\text{-S-}CH_2\text{-S-}C_2H_5$
238	Phosalone (Zolone)	S-[(6-Chloro-2-oxo-3-benzoxazolinyl)methyl]0, 0-diethyl phosphorodithioate	
239	Phosfolan (Cyolane)	P,P-Diethyl cyclic ethylene ester of phosphonodithioimidocarbonic acid	
240	Phosmet (Imidan)	0,0-Dimethyl-S-phthalimidomethyl phosphorodithioate	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

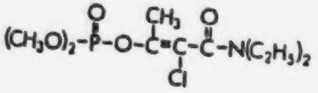
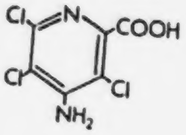
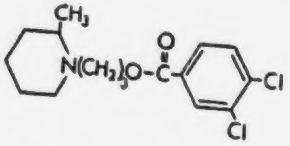
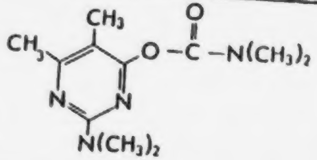
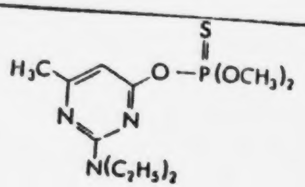
	Common Name	Chemical Name	Structure
241	Phosphamidon (Dimecron)	2-Chloro-N,N-diethyl-3-hydroxycrotonamide dimethyl phosphate	 $(CH_3O)_2-\overset{O}{\overset{\|}{P}}-O-\overset{CH_3}{\overset{\mid}{C}}=\underset{Cl}{\underset{\mid}{C}}-\overset{O}{\overset{\|}{C}}-N(C_2H_5)_2$
242	Picloram (Trodon)	4-Amino-3,5,6-trichloropicolinic acid	
243	Piperalin (Pipron)	3-(2-Methylpiperidino)propyl-3,4-dichlorobenzoate	
244	Pirimicarb (Pirimor)	2-(Dimethylamino)-5,6-dimethyl-4-pyrimidinyl dimethylcarbamate	
245	Pirimiphos Methyl (Actellic)	O-[2-(Diethylamino)-6-methyl-4-pyrimidinyl] O,O-dimethyl phosphorothioate	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

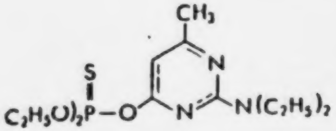
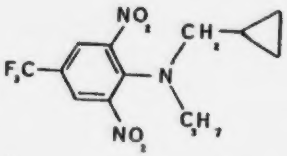
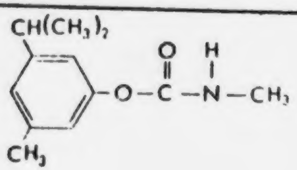
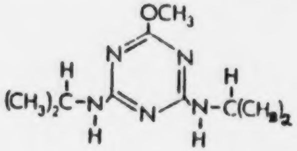
	Common Name	Chemical Name	Structure
246	Pirimiphos Ethyl (Primicid)	O-[2-(Diethylamino)-6-methyl-4-pyrimidinyl] O,O-diethyl phosphorothioate	
247	Potassium Azide (Kazoe)	Potassium azide	$K-N=N\equiv N$
248	Profluralin	N-cyclopropylmethyl-2,6-dinitro-N-propyl-4-trifluoromethylaniline	
249	Promecarb (Carbamult)	m-Cym-5ylmethylcarbamate	
250	Prometon (Pramitol)	2,4-Bis(isopropylamino)-6-methoxy-s-triazine	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

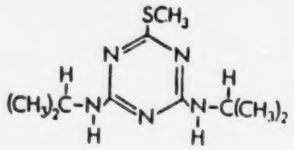
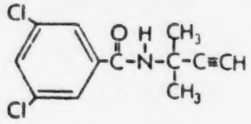
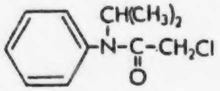
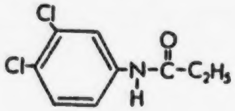
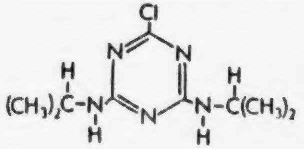
Common Name	Chemical Name	Structure
251 Prometryn (Caparol)	2,4-Bis(isopropylamino)-6-(methylthio)-s-triazine	
252 Pronamide (Kerb)	3,5-Dichloro-N-(1,1-dimethyl-2-propynyl) benzamide	
253 Propachlor (Ramrod)	2-Chloro-N-isopropylacetanilide	
254 Propanil (Rogue)	3,4-Dichloropropionanilide	
255 Propazine (Milogard)	2-Chloro-4,6-bis(isopropylamino)-s-triazine	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

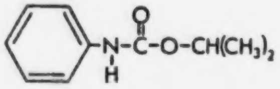
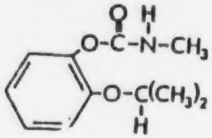
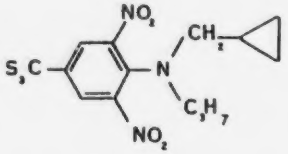
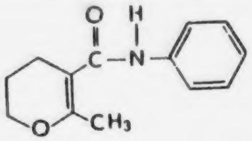
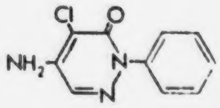
	Common Name	Chemical Name	Structure
256	Propham (IPC)	Isopropyl N-phenylcarbamate	
257	Propoxur (Baygon)	o-Isopropoxyphenyl N-methylcarbamate	
258	Prosulfin	N-cyclopropylmethyl-2,6-dinitro-N-propyl-4-trithiomethylaniline	
259	Pyracarbolid (Sicarol)	3,4-Dihydro-6-methyl-N-phenyl-2H-pyran-5-carboxamide	
260	Pyrazon (Pyramin)	5-Amino-4-chloro-2-phenyl-3(2H)-pyridazinone	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

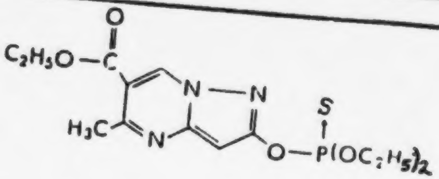
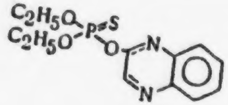
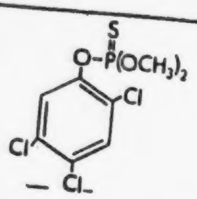
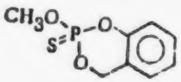
Common Name	Chemical Name	Structure
261 Pyrazophos (Afugon)	2-(0,0-Diethyl thionophosphoryl)-5-methyl-6-carbethoxy-pyrazolo(1,5a)-pyrimidine	
262 Quinalphos (Ekalux)	0,0-Diethyl 0-[quinoxalinyl-(2)] thionophosphate	
263 Ronnel	0,0-Dimethly 0-(2,4,5-trichlorophenyl) phosphorothioate	
264 Salithion	2-Methoxy-4H-1,3,2-benzodioxaphosphorin-2-sulfide	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

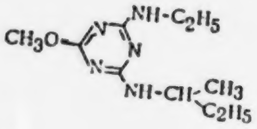
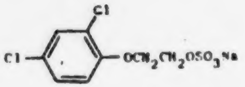
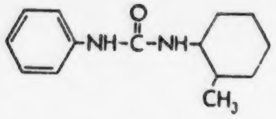
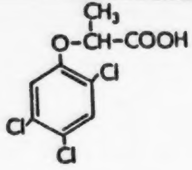
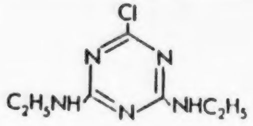
Common Name	Chemical Name	Structure
265 Secbumeton (Sumitol)	2-sec-butylamino-4-ethylamino-6-methoxy-1,3,5-s-triazine	
266 Sesone	2-(2,4-Dichlorophenoxy)ethanol hydrogen sulfate, sodium salt	
267 Siduron (Tupersan)	1-(2-Methylcyclohexyl)-3-phenylurea	
268 Silvex, Acid [2-(2,4,5-TP] and Esters	2-(2,4,5-Trichlorophenoxy) propionic acid, and esters	
269 Simazine (Princep)	2-Chloro-4,5,6-bis(ethyl-amino)-s-triazine	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

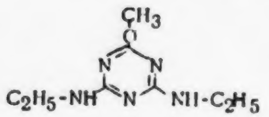
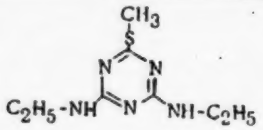
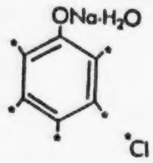
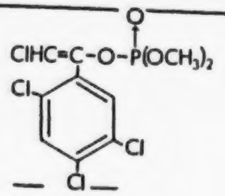
	Common Name	Chemical Name	Structure
270	Simetone (Gesadural)	2,4-bis(ethylamino)-6-methoxy-1,3,5-triazine	
271	Simetryne (Gy-bon)	2-Methylthio-4,6-bis-ethylamino-s-triazine	
272	Sodium Azide (Smite)	Sodium Azide	$Na-N=N\equiv N$
273	Sodium Pentachlorophenate (Dowicide G)	2,3,4,5,6-Pentachlorophenol, sodium salt, monohydrate	
274	Stirofos (Gardona)	2-Chloro-1-(2,4,5-trichlorophenyl)vinyl dimethyl phosphate	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

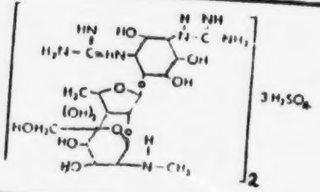
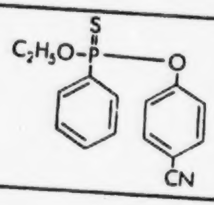
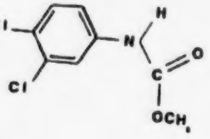
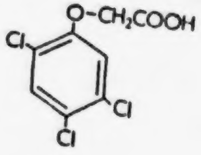
	Common Name	Chemical Name	Structure
275	Streptomycin Sulfate (Agri-Strep)	D-Streptamine, O-2-deoxy-2-(methylamino)-a-1-glucopyranosyl-(1-2)-O-5-deoxy-3-C-formyl-a-1-lyxofuranosyl-(1-4)-N-V-bis(aminoimmomethyl-, sulfate (2:3) (salt)	
276	Strobane	Polychlorinates of camphene, pinene and related terpenes	
277	Surecide (S4087)	O-(p-Cyanophenyl) O-ethyl phenylphosphonothioate	
278	Swep	methyl-3,4-dichlorophenylcarbamate	
279	2,4,5-T, Acid Esters, and Salts	2,4,5-Trichlorophenoxy-acetic acid, esters, and salts	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

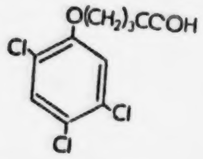
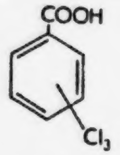
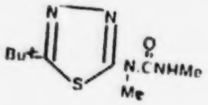
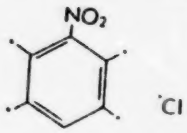
	Common Name	Chemical Name	Structure
280	4-(2,4,5-TB)	4-(2,4,5-Trichlorophenoxy) butyric acid	
281	2,36-TBA	2,3,6-Trichloro benzoic acid and related compounds	
282	TCA and its salts	trichloroacetic acid and its sodium salt	CCl_3-COOH CCl_3-COO^-Na^+
283	Tebuthiuron	1-(5-tert-butyl-1,2,4-thiadiazol-2-yl)-1,3-dimethylurea	
284	Tecnazene (Fusarex)	2,3,5,6-Tetrachloronitrobenzene	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

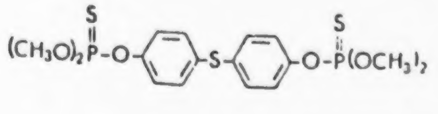
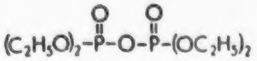
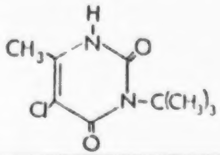
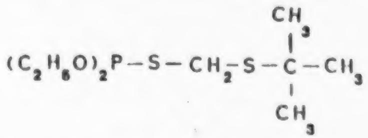
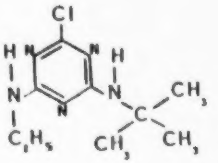
	Common Name	Chemical Name	Structure
285	Temephos (Abate)	O,O-Dimethyl phosphorothioate O,O-diester with 4,4'-thiodiphenol	
286	TEPP	Tetraethyl pyrophosphate	 $(C_2H_5O)_2-\overset{O}{\overset{\|}{P}}-O-\overset{O}{\overset{\|}{P}}-(OC_2H_5)_2$
287	Terbacil (Sinbar)	3-(tert-Butyl)-5-chlor-6-methyluracil	
288	Terbufos (Counter)	5-tert-butylthiomethyl O, O-dimethly phosphorodithioate	 $(C_2H_5O)_2P-S-CH_2-S-\overset{CH_3}{\underset{CH_3}{C}}-CH_3$
289	Terbuthylazine (GS-13529)	2-tert-butylamino-4-chloro-6-ethylamino-1,3,5-triazine	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

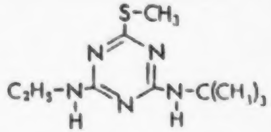
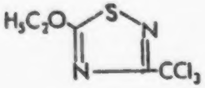
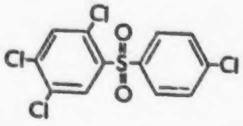
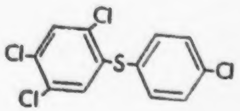
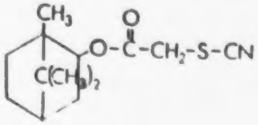
Common Name	Chemical Name	Structure
290 Terbutryn (Igran)	2-(tert-Butylamino)-4-(ethylamino)-6-(methylthio)-s-triazine	
291 Terrazole	5-Ethoxy-3-trichloromethyl-1,2,4-thiadiazole	
292 Tetradifon (Tedion)	4-Chlorophenyl 2,4,4-trichlorophenyl sulfone	
293 Tetrasul (Animert)	S-p-Chlorophenyl 2,4,5-trichlorophenyl sulfide	
294 Thanite	Isobornyl thiocyanoacetate	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

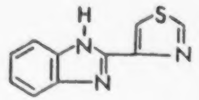
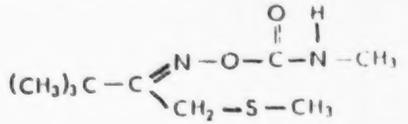
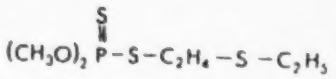
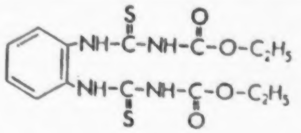
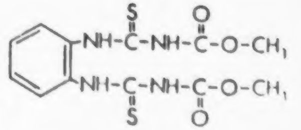
Common Name	Chemical Name	Structure
295 Thiabendazole (Mertect)	2-(4'-Thiazolyl) benzimidazole	
296 Thiofanox (DS-15647)	3,3-Dimethyl-1-(methylthio)-2-butamone 0-[(methylamino)-carbonyl]oxime	
297 Thiometon (Ekatin)	0,0-Dimethly S-[2-(ethylthio) ethyl] phosphorodithioate	 $(CH_3O)_2\overset{S}{\overset{\Vert}{P}}-S-C_2H_4-S-C_2H_5$
298 Thiophanate	1,2-Bis(3-ethoxycarbonyl-2-thioureido)benzene	
299 Thiophanate Methyl	1,2-Bis(3-methoxycarbonyl-2-thioureido)benzene	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

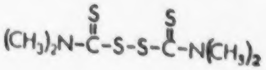
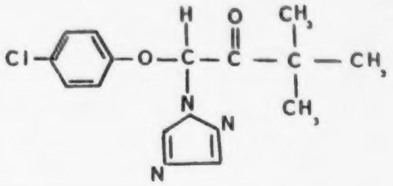
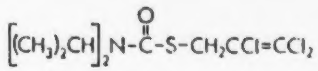
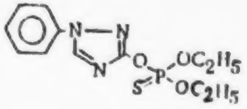
	Common Name	Chemical Name	Structure
300	Thiram (Arasan)	Tetramethylthiuram disulfide	 $(CH_3)_2N-\overset{S}{\overset{\|}{C}}-S-S-\overset{S}{\overset{\|}{C}}-N(CH_3)_2$
301	Toxaphene	A mixture of chlorinated camphene compounds of uncertain identity (combined chlorine 67-69%)	
302	Triadimefon (Bayleton)	1-(4-chlorophenoxy)-3,3-dimethyl-1-(1,2,4-triazol-1-yl)buton-2-one	
303	Triallate	S-(2,3,3-Trichloroallyl)-diisopropylthiocarbamate	 $[(CH_3)_2CH]_2N-\overset{O}{\overset{\|}{C}}-S-CH_2CCl=CCl_2$
304	Triazophos (Hostathion)	0,0-Diethyl 0-(1-phenyl-1H-1,2,4-triazol-3-yl)phosphorothioate	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

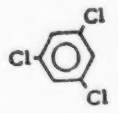
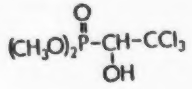
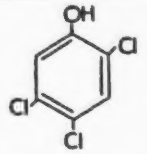
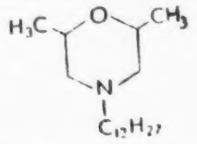
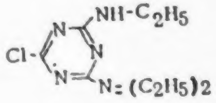
	Common Name	Chemical Name	Structure
305	Trichlorobenzenes (TCB, TCBA, Polystream)	1,2,4-Trichlorobenzene and isomers	
306	Trichlorofon (Dylox)	Dimethyl (2,2,2-trichloro-1-hydroxyethyl) phosphonate	 $(CH_3O)_2\overset{O}{\overset{\|}{P}}-\underset{OH}{\underset{\|}{CH}}-CCl_3$
307	2,4,5-Trichlorophenol (Dowicide 2)	2,4,5-Trichlorophenol	
308	Tridemorph (Calixin)	N-Tridecyl-2,6-dimethyl-morpholine	
309	Trietazine (Gesafloc)	2-chloro-4-ethylamino-6-diethylamino-s-triazine	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 1-ORGANIC PESTICIDES CHEMICALS

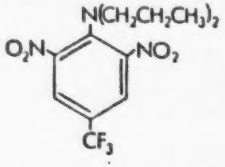
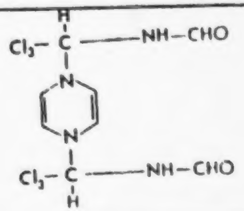
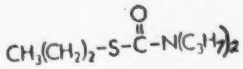
	Common Name	Chemical Name	Structure
310	Trifluralin (Treflan)	a,a,a-Trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine	
311	Triforine (Cela W524)	N,N'-[1-4-Piperazinediyl-bis-(2,2,2-trichloroethylene)]-bis(formamide)	
312	Vernolate (Vernam)	S-Propyl N,N-dipropylthio-carbamate	 $CH_3(CH_2)_2-S-\overset{O}{\overset{\parallel}{C}}-N(C_3H_7)_2$

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 2 - METALLO-ORGANIC PESTICIDES

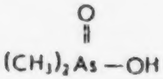
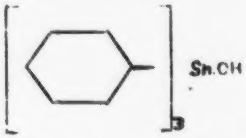
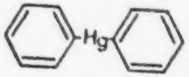
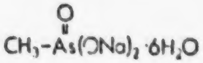
	Common Name	Chemical Name	Structure
313	Cacodylic Acid	Dimethylarsinic acid	 $(CH_3)_2\overset{O}{\overset{\parallel}{As}}-OH$
314	Calcium Arsenate	Calcium arsenate	$Ca_3(AsO_4)_2$
315	Cryolite (Kryocide)	Sodium Fluoaluminate	Na_3AlF_6
316	Cyhexatin	Tricyclohexytin hydroxide	
317	Diphenyl Mercury	Diphenyl mercury	
318	DSMA	Disodium methanearsonate, hexahydrate	 $CH_3-\overset{O}{\overset{\parallel}{As}}(ONa)_2\cdot 6H_2O$

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 2 - METALLO-ORGANIC PESTICIDES

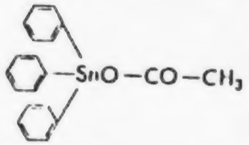
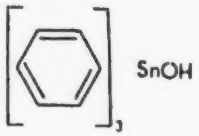
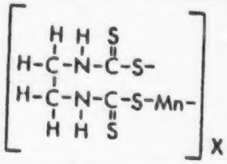
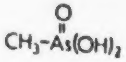
	Common Name	Chemical Name	Structure
319	Ethylmercury Chloride (Ceresan)	Ethylmercury Chloride	$CH_3CH_2-Hg-Cl$
320	Fentin Acetate (Brestan)	Triphenyltin acetate	
321	Fentin Hydroxide (Duter)	Triphenyltin hydroxide	
322	Lead Arsenate	Acid lead arsenate	$PbHAsO_4$
323	Maneb	Manganous ethylene-bis-(dithiocarbamate)	
324	Methanearsonic Acid (MAA)	Methyl arsonic acid	 $CH_3-\overset{\overset{O}{\|}}{As}(OH)_2$

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 2 - METALLO-ORGANIC PESTICIDES

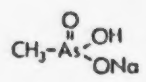
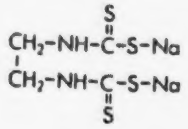
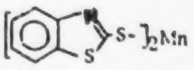
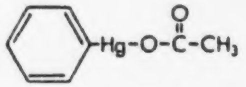
	Common Name	Chemical Name	Structure
325	Methylmercuric Chloride	Methylmercury chloride	CH_3-Hg-Cl
326	Methylmercuric Iodide	Methylmercury ioidide	CH_3HgI
327	MSMA (Bueno)	Monosodium acid methanearsonate	 $CH_3-\overset{O}{\overset{\parallel}{As}}\begin{smallmatrix}OH\\ONa\end{smallmatrix}$
328	Nabam	Disodium ethylene bis(dithiocarbamate)	 $\begin{matrix}CH_2-NH-\overset{S}{\overset{\parallel}{C}}-S-Na\\ \vert \\ CH_2-NH-\underset{S}{\underset{\parallel}{C}}-S-Na\end{matrix}$
329	Niacide	manganeous benzothiazyl mercaptide	
330	Phenylmercuric Acetate (Common name PMA)	Phenylmercury acetate	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 2 - METALLO-ORGANIC PESTICIDES

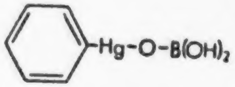
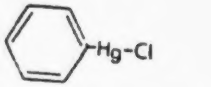
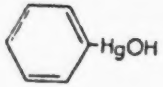
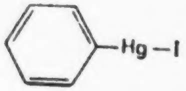
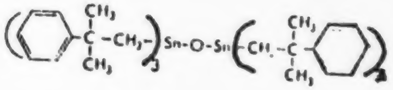
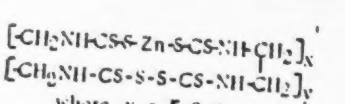
	Common Name	Chemical Name	Structure
331	Phenylmercuric Borate	Phenylmercury borate	
332	Phenylmercuric Chloride	Phenylmercury chloride	
333	Phenylmercuric Hydroxide	Phenylmercury hydroxide	
334	Phenylmercuric Iodide	Phenylmercury iodide	
335	Vendex	Hexakis (B,B-dimethyl-phenethyl)-distannoxane	
336	Zinc Metiram	Mixture of [ethylenebis (dithiocarbamato)] zinc ammoniates with ethylenebis [dithiocarbamic acid] anhydrosulfides	 $[-CH_2NH-CS-S-Zn-S-CS-NH-CH_2]_x$ $[-CH_2NH-CS-S-S-CS-NH-CH_2]_y$ where $x = 5.2$ times y

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

SUBCATEGORY 2 - METALLO-ORGANIC PESTICIDES

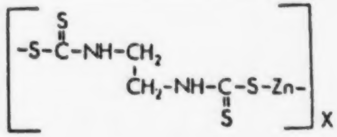
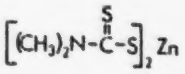
	Common Name	Chemical Name	Structure
337	Zineb	Zinc ethylenebisdithiocarbamate	
338	Ziram	Zinc dimethyldithiocarbamate	 $\left[(CH_3)_2N-\overset{\overset{S}{\parallel}}{C}-S\right]_2Zn$

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

NON-CATEGORIZED PESTICIDES

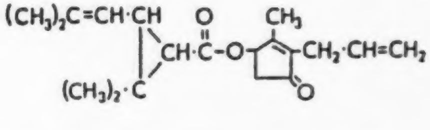
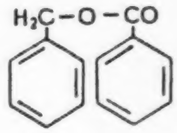
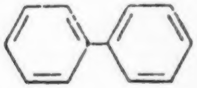
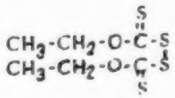
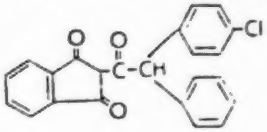
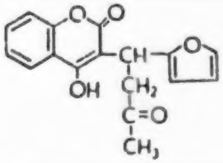
	Common Name	Chemical Name	
339	Allethrin	2-Allyl-4-hydroxy-3-methyl 2-cyclopenten-1-one ester of 2,2-dimethyl-3-(2-methyl-propenyl)-cyclopropane-carboxylic acid	
340	Benzyl Benzoate	Benzyl benzoate	
341	Biphenyl (Diphenyl)	Biphenyl	
342	Bisethylxanthogen	bis (ethylxanthic) disulfide	
343	Chlorophacinone (Rozol)	2-[(p-Chlorophenyl) phenyl-acetyl]-1,3-indandione	
344	Coumafuryl (Fumarin)	3-(a-Acetonylfurfuryl)-4-hydroxycoumarin	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

NON-CATEGORIZED PESTICIDES

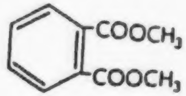
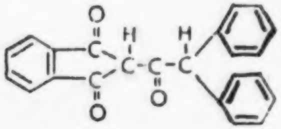
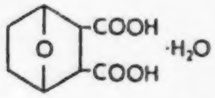
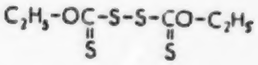
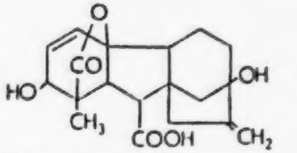
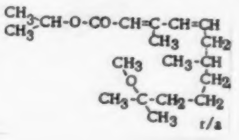
Common Name	Chemical Name	
345 Dimethyl Phthalate	Dimethyl Phthalate	
346 Diphacinone	2-Diphenylacetyl-1,3-indandione	
347 Endothall, Acid	7-Oxabicyclo(2.2.1)heptane-2,3-dicarboxylic acid monohydrate	
348 EXD (Herbisan)	Diethyl dithiobis(thionoformate)	 $C_2H_5\text{-O}\underset{\overset{\|}{S}}{C}\text{-S-S-}\underset{\overset{\|}{S}}{C}\text{O-}C_2H_5$
349 Gibberellic Acid	Gibb-3-ene-1,10-dicarboxylic acid,2,4a,7-trihydroxy-1-methyl-8-methylene-1,4a-lactone	
350 Methoprene (Altosid)	Isopropyl (2E,4E)-11-methoxy-3,7,11-trimethyl-1,4-dodecadienoate	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

NON-CATEGORIZED PESTICIDES

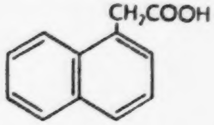
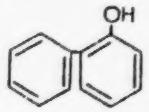
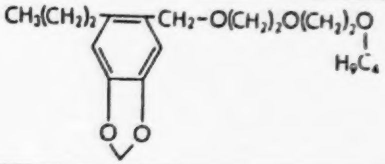
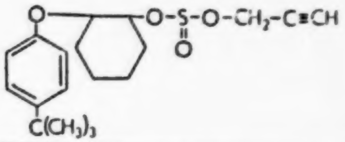
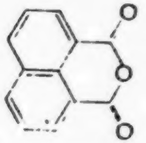
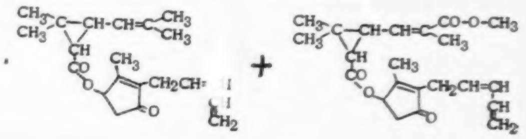
	Common Name	Chemical Name	Structure
351	NAA (Naphthalene Acetic Acid)	1-Naphthalene acetic acid	
352	Phenylphenol (Dowicide 1)	o-Phenylphenol	
353	Piperonyl Butoxide	a-[2-(butoxyethoxy)ethoxy]-4,5-methylenedioxy-2-propyltoluene	
354	Propargite (Omite)	2-(p-tert-Butylphenoxy)cyclohexyl2-propynyl suflite	
355	Protect	1,8-Naphthalic anhydride	
356	Pyrethrins	Standardized mixture of pyrethrins I and II (Mixed esters of pyrethrolone)	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

NON-CATEGORIZED PESTICIDES

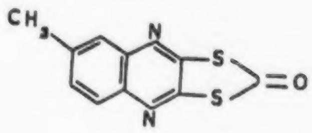
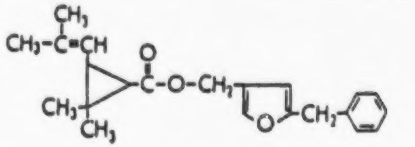
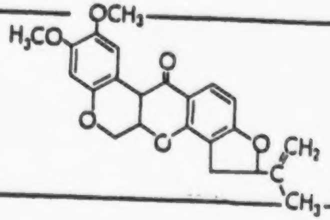
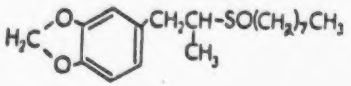
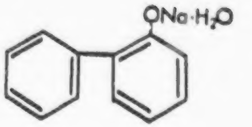
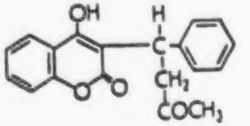
	Common Name	Chemical Name	Structure
357	Quinomethionate (Morestan)	6-methly-2-oxo-1,3-dithiolo [4,5-b]quinoxaline	
358	Resmethrin (SBP-1382)	(5-Benzyl-3-furyl)methyl-2, 2-dimethyl-3-(2-methyl propenyl)cyclopropane-carboxylate (approx. 70% trans, 30% cis isomers)	
359	Rotenone	1,2,12,12a, Tetrahydro-2-isopropenyl-8,9-dimethoxy-[1] benzopyrano-[3,4-b]furo [2,3-b][1] benzopyran-	
360	Sulfoxide	1-Methyl-2-(3,4-methylane-dioxyphenyl)ethyl octyl sulfoxide	
361	Sodium Phenylphenate (Dowicide A)	o-Phenylphenol, sodium salt, monohydrate	

TABLE X-1
INDEX OF PESTICIDE COMPOUNDS BY SUBCATEGORY

NON-CATEGORIZED PESTICIDES

Common Name	Chemical Name	Structure
362 Warfarin	3-(a-Acetonylbenzyl)-4-hydroxycoumarin	

SECTION XI

ACKNOWLEDGEMENTS

This report was prepared by the Environmental Protection Agency on the basis of a comprehensive study performed by Environmental Science and Engineering, Inc., under contract No. 68-01-3297 and under the direction of John D. Crane, P. E., and the management of Mr. James B. Cowart, P.E.. Key ESE staff members included Dr. John D. Bonds, Mr. Edward M. Kellar, Mr. Charles Stratton, Dr. Don Tang, P. E., Dr. Ruey Lai, Mr. Stu Monplaisir, Mr. Bevin Beaudet, P.E., Mr. Mark Mangone, Mr. Ernie Frey and Ms. Elizabeth Brunetti.

The study was conducted under the supervision and guidance of Mr. George M. Jett, Project Officer. The work was supervised by Dr. W. Lamar Miller, Organic Chemicals Branch Chief, and Mr. Michael Kosakowski. Able assistance was provided by Mr. Robert Dellinger, Mr. Joseph Vitalis and Dr. Hugh Wise of the Organic Chemicals Branch.

The project officer wishes to acknowledge the assistance of the personnel at the Environmental Protection Agency's regional centers who helped identify those plants achieving effective waste treatment, and whose efforts provided much of the research necessary for the treatment technology review. Appreciation is extended to Mr. James Rogers, Mr. Colburn T. Cherney and Mr. Barry Malter of the EPA Office of General Counsel, to Dr. Henry Kahn and Dr. Charles Cook for their assistance on the statistical analyses; Dr. Gregory Kew of the Office of Enforcement; Mr. Richard Busse of the Office of Planning and Management, Mr. Charles Gregg and Ms. JoAnn Bassi of the staff of the Office of Water and Hazardous Materials, and to Mr. Louis DuPuis for his evaluation of the economic impact of this regulation.

Acknowledgement is made of the cooperation of personnel in many plants in the pesticide chemicals manufacturing industry who provided valuable assistance in the collection of data relating to process raw waste loads and treatment plant performance.

The project personnel would also like to thank Dr. Walt Sanders, Dr. Lee Wolfe, Dr. James Lichtenburg, Dr. James Longbottom , Dr. Dale Denny, Mr. Dave Oestreich, Dr. Atly Jefcoat, and Mr. Paul DesRosiers of EPA's Office of Research and Development, for their technical assistance during this study.

Acknowledgement and appreciation is extended to Ms. Kaye Starr, Ms. Nancy Zrubek, Ms. Carol Swann and Ms. Pearl Smith for invaluable support in coordinating the preparation and reproduction of this report; to Mr. Tom Tape, Mr. Todd Williams, and Mr. Allen Bradley for proofreading, filing, organizing, etc., to Mr. Eric Yunker, Ms. Mable Scales, Ms. Middie Jackson and Ms. Coleen Tresser of the Effluent Guidelines Division secretarial staff for their efforts in the typing of drafts, necessary revision, and final preparation of the revised development document.

SECTION XII

BIBLIOGRAPHY

1. Addison, J.B., et al. "The Photochemical Reactions of Carbamates II. The Solution Photochemistry of Matacil (4-dimethyl-aminom-tolyl-N-methyl carbamate) and landrin (3,4,5-trimethylphenylN-methyl carbamate)," Bulletin of Environmental Contamination and Toxicology, 11(3), 1974.

2. AICHE Environmental Division. "Industrial Process Design for Pollution Control," Vol. 4; October, 1971.

3. Aly, O.M. and El-Dib, M.A. "Studies on the Persistence of Some Carbamate Insecticides in the Aquatic Environment--I, Hydrolysis of Sevin, Baygon, Pyrolan, and Dimetilan in Waters." Water Research, Pergamon Press, 1971. Vol. 5, pp. 1191-1205.

4. Aly, O.M., and Faust, S.D. "Removal of 2,4-Dichlorophenoxyacetic Acid Derivatives from Natural Waters," JAWWA, 57(2) (Feb. 1965).

5. Aly, O.M. and Faust, S.D. "Studies on the Fate of 2,4-D and Ester Derivatives in Natural Surface Waters," Agricultural and Food Chemistry Vol. 12, No. 6, Nov.-Dec. 1964.

6. American Public Health Association. Standard Methods for Examination of Water and Waste Water, 13th Ed.; APHA, Washington, D.C., 20036, 1971.

7. American Society of Mechanical Engineers, Research Committee on Industrial Wastes, Incineration of Chlorinated Hydrocarbons with Recovery of HCL at E.I. duPont de Nemours & Company. Louisville, Kentucky.

8. Anderson, D.W. and Risebrough, R.W. (Article), Science, Volume 193, pp. 96-97, (Division of Wildlife and Fisheries, Biology, Univ. of California, Davis 95616).

9. APHA, ASCE, AWWA, and WPCF. Glossary of Water and Wastewater Control Engineering,
American Society of Civil Engineers; New York, 1969.

10. Archer, T.E. and Crosby, D.G. "Gas Chromatographic Measurement of Toxaphene in Milk, Fat, Blood, and Alfalfa Hay," Bulletin of Experimental Contamination &

Toxicology, Vol. 1, No. 2, 1966 by SpringerVerlag, New York, Inc.

11. Arkansas, City of Jacksonville. Biological Treatment of Chlorophenolic Wastes, (for U.S. EPA Water Quality Office Project No. 12130, June, 1971; EP2. 10:12130 EGK 06/71).

12. Armstrong, D.E. and Chesters, G. "Adsorption Catalyzed Chemical Hydrolysis of Atrazine," Environmental Science and Technology, 2(9):683-689 (1968).

13. Armstrong, D.E., Chesters, G., and Harris, R.F. "Atrazine Hydrolysis in Soil," Soil Science Society American Processes, Vol. 31 (1967).

14. Arthur D. Little, Inc. Sampling Program to Obtain Information on the Treatability of Wastewater by Activated Carbon Absorption Systems, for EPA, Effluent Guidelines Development Branch, Washington, D.C., Interim Report, May 1976.

15. Association of American Pesticide Control Officials, Inc. Pesticide Chemicals Official Compendum. 1966 edition (available from Kansas State Board of Agriculture, Topeka, Kansas).

16. Associated Water and Air Resources Engineers, Inc. Evaluation of Biological Treatment Feasibility for a Wastewater from Herbicide Production (for Ciba-Geigy), Nashville, Tennessee. March, 1973.

17. Atkins, Patrick A. The Pesticide Manufacturing Industry--Current Waste Treatment and Disposal Practices. U.S. EPA, Office of Research and Monitoring. Project #12020 FYE (January 1972).

18. Bailey, G.W. and White, J.L. "Herbicides, a Compilation of Their Physical, Chemical, and Biological Properties," Residue Review, Vol. 1, pp. 97-122, Springer-Verlag, New York, New York, 1965.

19. Battelle. Program for the Management of Hazardous Wastes, for U.S. EPA, Office of Solid Waste Management Programs, July 1973.

20. Beebe, R.L. Activated Carbon Treatment of Raw Sewage in Solids-Contact Clarifiers, U.S. EPA, R2-73-183, NERC, Cincinnati, Ohio 45268, March, 1973.

21. Bell, H.L. An Appraisal of Pesticide Usage and Surface Water Quality Effects in the United States, EPA, Office of Enforcement, National Field Investigations Center, Denver, Colo., April 1974.

22. Bellus, D. and Hrdlovic, P. "Photochemical Rearrangement of Aryl, Vinyl, and Substituted Vinyl Esters and Amides of Carboxylic Acids," Chemical Reviews, 67, (6), November 24, 1967.

23. Bender, M.L. "Mechanisms of Catalysis of Nucleophilic Reactions of Carboxylic Acid Derivatives," Chemical Review, 60:53 (1960).

24. Bender, M.L. and Homer, R.B. "The Mechanism of the Alkaline Hydrolysis of the p-Nitrophenyl N-Methylcarbamate," J. Org. Chem., 30:3975, November 1965.

25. Berg, Gorden L., Editor. Farm Chemicals Handbook, 1973, Meister Publishing Co., Willoughby, Ohio 44094.

26. Bernardin, F.E., Jr. and Froelich, E.M. "Practical Removal of Toxicity by Adsorption," 30th Annual Purdue Industrial Waste Conf. (May 8-9, 1975).

27. Binkley, R.W. and Oakes, T.R. "Photochemical Reactions of Methyl Phenoxyacetates," Journal of Organic Chemistry, 39, (1), 1974.

28. Black, Crow, and Eidsnes, Inc. The Effects of Toxaphene on Sewage Treatment, Project No. 70-01-75; Houston, Texas, September 1971.

29. Blecker, H.G. and Cadman, T.W. "Capital and Operating Costs of Pollution Control Equipment Modules--Vol. I--User Guide," Socioeconomic Environmental Studies Series (July 1973) EPA-R5-73-023a.

30. Blecker, H.D. and Nichols, T.M. "Capital and Operating Costs of Pollution Control Equipment Modules, Volume II--Data Manual," Socioeconomic Environmental Studies Series (July 1973), EPA-R5-73-023a.

31. Bordeleau, L.M. and Bartha, R. "Biochemical Transformation of Herbicide Derived Anilines in Culture Medium and in Soil," Canadian Journal of Microbiology, Vol. 18, pp. 1857-1864 (1972).

32. Borthwick, P.W., *et al*. "Residues in Fish, Wildlife, and Estuaries," *Pesticides Monitoring Journal*, *7*, (3/4) (March 1974).

33. Boucher, F.R. and Lee, G.F. "Adsorption of Lindane and Dieldrin Pesticides on Unconsolidated Aquifer Sands," *Environmental Science and Technology*, 6(6), (June 1972).

34. Boyle, H. "Analysis of Raw Sewage Sludge and Effluent for Chlorinated Insecticides for the Los Angeles County Sanitation District," *Waste Identification and Analysis*, AWTRL, NERC-Cincinnati, U.S. EPA (Jan. 29, 1971).

35. Brooks, G.T. "Chlorinated Insecticides," *Technology and Application*, Vols. I and II, University of Sussex, CRC Press, Inc. (1974).

36. Brown, N.P.H., Furmidge, C.G.L., and Grayson, B.T. "Hydrolysis of the Triazine Herbicide, Cyanazine," *Pesticide Science*, 3:669-678, (1972).

37. Buesche, C.A., *et al*. "Chemical Oxidation of Selected Organic Pesticides," *Journal of the Water Pollution Control Federation*, 36(8):1005-1014; August, 1964.

38. Bunker, R.C., *et al*. *Plant Responses of Natural Vegetation to Selected Herbicides at Aberdeen Proving Ground, Maryland*, U.S. Department of the Army, Fort Detrick, Frederick, Maryland (September 1971).

39. Burges, H.D. and Hussey, N.W. *Microbial Control of Insects and Mites*, Academic Press, New York, 1971.

40. Burns, J.E. and Miller, F.M. "Hexachlorobenzene Contamination: Its Effects in a Louisiana Population," *Archives of Environmental Health*, American Medical Association, Vol. 30 (Jan. 1975).

41. Burns, J.E., *et al*. "Hexachlorobenzene Exposure from Contaminated DCPA in Vegetable Spraymen," *Archives of Environmental Health*, American Medical Association, Vol. 29 (Oct. 1974).

42. Burns, J.E. "Pesticides in People," *Pesticides Monitoring Jourl*, *7*, (3,4)(March 1974).

43. Calgon Corporation. *Basic Concepts of Adsorption of Activated Carbon*, Calgon Adsorption Systems, Pittsburgh, Pa. 15230, 1973.

44. Calgon Corporation. *Basic Concepts of Adsorption of Activated Carbon*, Pa. 15230, 1974.

45. Canada, Department of Agriculture. *Guide to the Chemicals Used in Crop Protection*, 4th Edition, Publication 1093, Ottawa, Canada, April, 1961.

46. Canada, Department of Agriculture. *International Symposium on Identification and Measurement of Environmental Pollutants--Abstracts*, Ottawa, Canada, June 14-17, 1971.

47. Carnahan, R.P. "Mathematical Modeling of Heterogeneous Sorption in Continuous Contactors for Wastewater Decontamination," a dissertation to faculty of Clemson University, Environmental Systems Engineering, Dec. 1973.

48. Carnes, R.A., Oberacker, D.A. "Pesticide Incineration," *News of Environmental Research in Cincinnati*, U.S. EPA (April 15, 1976).

49. CCI Environmental Systems Division. *Incineration of DDT Solutions*, Report S-1276, prepared for the Sierra Army Depot, Herlon, California, January 1974.

50. Chadwick, R.W., *et al*. "The Effect of Age and Long-Term Low-Level DDT Exposure on the Response to Enzyme Induction in the Rat," *Toxicology and Applied Pharmacology*, Academic Press, Inc., March, 1975.

51. Cheremisinoff, P.N. and Feller, S.M. "Wastewater Solids Separation," *Pollution Engineering*.

52. Children's Hospital Medical Center. "Report of the Advisory Committee on 2,4,5-T to the Administrator of the Environmental Protection Agency," May 7, 1971.

53. Ciba-Geigy Corporation. *Environmental Impact of S-Triazine Compounds Discharged to the Mississippi River*, St. Gabriel, Louisiana, February 1, 1973.

54. Ciba-Geigy Corporation. *Water Pollution Control Program*, Request for Discharge Standards under Corps of Engineers Discharge Permit Application No. 172D-000696; June 20, 1973.

55. Cohen, J.M., et al. "Effect of Fish Poisons on Water Supplies, Part I, Removal of Toxic Materials," JAWWA, 52(12):1551, Dec. 1960.

56. Coley, G. and Stutz, C.H. "Treatment of Parathion Wastes and Other Organics," JWPCF, 38(8) (1966).

57. Comptroller General of the United States. Federal Efforts to Protect the Public from Cancer Causing Chemicals are not very Effective, Report to the Congress, June 16, 1976.

58. Conway, R.A. Treatability of Wastewater From Organic Chemicals and Plastics Manufacturing - Experience and Concepts, Research and Development Department, Chemicals and Plastics, Union Carbide Corporation, South Charleston, West Virginia, September, 1974.

59. Council on Environmental Quality, 1974. Production, Distribution, Use and Environmental Impact Potential of Selected Pesticides, MIR, Final Report, Feb. 25, 1973 - March 15, 1974, Contract No. EQ-311.

60. Cowart, R.P., et al. "Rate of Hydrolysis of Seven Organophosphate Pesticides," Bull. of Environ. Contam. & Toxicol., 6(3), (1971).

61. Cranmer, M.F. and Peoples, A.J. "Determination of Trace Quantities of Anticholinesterase Pesticides," Analytical Biochemistry, 55, Academic Press, 1973.

62. Cranmer, M.F. and Peoples, A.J. "Measurement of Blood Cholinesterase Activity in Laboratory Animals Utilizing Dimethylbutyl Acetate as a Substrate," Laboratory Animal Science, American Assoc. for Laboratory Animal Science, 23(6) (1973).

63. Cristol, S.J. "The Kinetics of the Alkaline Dehydrochlorination of the Benzene Hexachloride Isomers. The Mechanism of Second-Order Elimination Reactions," J. Am. Chem. Soc., 69:338 (1947).

64. Crockett, A.B., et al. "Pesticides in Soil," Pesticides Monitoring Journal, 8, (2) (Sept. 1974).

65. Cronan, C.S., editor-in-chief. "Activated-Sludge Process Solves Waste Problem," Chemical Engineering, 68, (2), (January 23, 1961).

66. Cronan, C.S., editor-in-chief. "Meanwhile, Persistent but Nontoxic Insecticides Chemically Similar to D.D.T.," Chemical Engineering, Aug. 9, 1971.

67. Cronan, C.S., editor-in-chief. "Production of the Pesticides Aldrin and Dieldrin has been Suspended," Chemical Engineering, (Oct. 14, 1974).

68. Cronan, C.S., editor-in-chief. "Suspension of the Sale of Insecticides Chlordane and Heptachlor," Chemical Engineering, (Aug. 18, 1975).

69. Cronan, C.S., editor-in-chief. "A System for Removing Trace Amounts of Pesticides from Wastewater," Chemical Engineering, (Aug. 9, 1971).

70. Crosby, D.G. "The Nonmetabolic Decomposition of Pesticides," Ann. N.Y. Acad. Sci., 160, 82 (1969).

71. Crosby, D.G., et al. "Photodecomposition of Carbamate Insecticides," J. Agr. Food Chem., 13(3), Man-June, 1965.

72. Crosby, D.G. and Wong, A.S. "Photodecomposition of 2,4,5-Trichlorophenoxyacetic Acid (2,4,5-T) in Water," J. Agr. Food Chem., 21, (6), 1973.

73. Crosby, D.G., Tutass, H.O. "Photodecomposition of 2,4-Dichlorophenoxyacetic Acid," J. Agr. Food Chem., 14, (6), November-December, 1966.

74. Davidson, J.M., et al. "Use of Soil Parameters for Describing Pesticide Movement Through Soils," U.S.E.P.A. Project No. R-800364, EPA-660/2-75-009, (May, 1975).

75. Davies, J.E., et al. "The Role of House Dust in Human DDT Pollution," AJPH, 65, (1) (Jan., 1975).

76. Davis, E.M., Petros, J.K., and Power, E.L. "Organic Biodegradation in Hypersaline Wastewater," Manufacturing, January/February, 1977.

77. Davis, K.E. and Funk, R.J. "Deep Well Disposal of Industrial Waste," Industrial Waste, January - February, 1975.

78. Davis, L.E., et__ al__. "Central Nervous System Intoxication from Mercurous Chloride Laxatives,"

Archives of Neurology, Amer. Med. Assoc., Vol. 30 (June, 1974).

79. Dean, J.A., editor. *Lange's Handbook of Chemistry*, 11th Edition, McGraw-Hill Book Company, New York, N.Y., 1973.

80. DeJohn, P.B. and Adams, A.D. "Activated Carbon Improves Wastewater Treatment," *Hydrocarbon Processing*, October, 1975.

81. Dougherty, R.C., *et al*. "Positive and Negative Chemical Ionization Mass Spectra of Some Aromatic Chlorinated Pesticides," *Analytical Chemistry*, American Chemical Society, *47*, (1), (January, 1975).

82. Eckenfelder, W.W., Jr. "Development of Operator Training Materials," Environmental Science Services Corp., Stamford, Conn., August, 1968.

83. Eckenfelder, W.W., Jr. *Water Quality Engineering for Practicing Engineers*, Barnes and Noble, Inc., New York, N.Y., 1970.

84. *The Effects of Pesticides on Water Resource Development*, a series of papers presented at the Joint Meeting of the Arkansas-White Basins Inter-Agency Committee and the Southeast Basins Inter-Agency Committee, New Orleans, Louisiana, April 22, 1970. Eichelberger, J.W. and Lichtenberg, J.J. "Carbon Adsorption for Recovery

85. Eichelberger, J.W. and Lichtenberg, J.J. "Carbon Adsorption for Recovery of Organic Pesticides," *JWPCF*, *63*(1) (Jan., 1971).

86. Eisenhauer, H.R. "Oxidation of Phenolic Wastes, Part I: Oxidation with Hydrogen Peroxide and a Ferrous Salt Reagent," *JWPCF*, *36*(9) (Sept., 1964).

87. England, British Crop Protection Council, *Pesticide Manual*, 3rd Edition, Hubert Martin, Editor; November, 1972.

88. Enviro-Lab, Inc. *Completion Report Wastewater Treatability Studies Vicksburg Chemical Company, Vicksburg, Mississippi*, August 31, 1975.

89. Farmer, W.J. and Letey, J. "Volatization Losses of Pesticides from Soils," Environmental Protection Technology Series, (August, 1974), EPA 660/2-74-054.

90. Faust, S.D. and Aly, O.M. "Water Pollution by Organic Pesticides," J. AWWA, Vol. 56, No. 3, March, 1964.

91. Faust, S.D. and Gomma, H.M. Environmental Letters, 3(171), 1972.

92. Faust, S.D. and Gomma, H.M. "Kinetics of Hydrolysis of Diazonon and Diazoxan," Residues Reviews, 29 (1969).

93. Federal Water Pollution Control Administration. "Report of the Committee on Water Quality Criteria," U.S. Government Printing Office, 1968.

94. Federal Working Group on Pesticide Management. Proceeding of the National Conference on Protective Clothing and Safety Equipment for Pesticide Workers, Washington, D.C., June, 1972.

95. Ferguson, T.L. Pollution Control Technology for Pesticide Formulators and Packagers, EPA 660/2-74-094, (January, 1975).

96. Frear, E.H., Ph.D. Pesticide Index, Fourth Edition, College Science Publishers, State College, PS 16801, 1969.

97. Forestell, W.L., editor-in-chief. "Get Ready, Hazardous Wastes are Coming Your Way," The American City and County, (August, 1976).

98. Fornwalt, H.J. and Hutchins, R.A. "Purifying Liquids with Activated Carbon," Chemical Engineering, April 11, 1966.

99. Fox, M., et al. " -Chlorobenzene," J. of Amer. Chem. S., 95(24), November 28, 1973.

100. Fox, R.D., "Pollution Control at the Source," Chemical Engineering, 80, (18) August 6, 1973.

101. Gabica, J., et al. "Rapid Gas Chromatographic Method of Screening of Pesticide Residues in Milk," Journal of the Assoc. of Official Analytical Chemists, Vol. 57 (Jan., 1974).

102. Garrison, A.W. *Comments on Development Document for Guidelines for the Pesticides Industry*, EPA, Athens, Georgia 30601, August 2, 1976.

103. Goldstein, J.A., *et al*. "Experimental Hepatic Porphyria Induced by Polychlorinated Biphenyls," *Toxicology and Applied Pharmacology*, 27 (1974).

104. Golz, H.H. and Schaffer, C.B. *Toxicological Information on Cyanamid Insecticides*, American Cyanamid Co., Princeton, N.J.

105. Gomma, H.M. and Faust, S.D. "Chemical Hydrolysis and Oxidation of Parathion and Paraoxon in Aquatic Environments," *Fate of Organic Pesticides in the Aquatic Environment*, Advances in Chem. Series III, ACS, Washington, D.C., 1971.

106. Gonzalez, J.G. and Ross, R.T. "Interfacing of an Atomic Absorption Spectrophotometer with a Gas-Liquid Chromatograph for the Determination of Trace Quantities of Aklyl Mercury Compounds in Fish Tissue," *Analytical Letters*, EPA, *5*(10), (1972).

107. Goodrich, P.R. and Monke, E.J. "Insecticide Adsorption on Activated Carbon," *Transactions of Am. Society of Agr. Engineers*, 13(1) (Jan/Feb, 1970).

108. Gould, M.S. and Genetelli, E.J. "Heavy Metal Distribution in Anaerobically Digested Sludges," a paper presented at the 30th Annual Purdue Industrial Waste Conference, May 7, 1975.

109. Grandjacque, B. *Air Pollution Control and Energy Saving with Carbon Adsorption Systems*, Report No. APC. 12-A, Calgon Corp., Activated Carbon Division, July 18, 1975.

110. Gunther, F.A. "Reported Solubilities of 738 Pesticide Chemicals in Water," *Residue Review*, Vol. 20, pp. 1-148, Springer-Verlag, New York, N.Y., 1968.

111. Gunther, F.A. and Blinn, R.C. *Analysis of Insecticides and Acancides*, Interscience Publishers, Inc., New York (1955).

112. Gunther, F.A. and Gunther, J.D., editors. *Residue Reviews*, *36*, 262 (1971).

113. Gysin, H. and Knuesli, E. "Chemistry and Herbicidal Properties of Triazine Derivatives," Adv. Pest Control Research, Vol. 4, p. 249, (1961).

Hager, D.G. "Industrial Wastewater Treatment by Granular Activated Carbon," Ind. Water Eng., (Jan/Feb, 1974).

114. Hagar and Rizzo. "Removal of Toxic Organics from Wastewater by Adsorption with Granular Carbon," a paper presented at EPA, Technical Transfer Session, Athens, Georgia, April 19, 1974.

115. Hannah, S.A., Jelus, M., and Cohen, J.M. "Removal of Uncommon Trace Metals by Physical and Chemical Treatment Processes," U.S. EPA, Wastewater Research Division, October, 1976.

116. Haque, Rizwanul and Freed, V.H. Environmental Dynamic of Pesticides, Plenum Press, New York, N.Y., 1975.

117. Heath, D.F. Organophosphorus Poisons, Pergamon Press, New York (1961).

118. Hemmett, R.B., Jr. and Faust, S.D. "Biodegradation Kinetics of 2,4dichlorophenoxyacetic acid by Aquatic Microorganisms," Residue Reviews, 29 (1969).

119. Hemphill, D.D., editor. "Trace Substances in Environmental Health-IV," proceedings of University of Missouri's 4th Annual Conference on Trace Substances in Environmental Health, June 23, 24, 25, 1970.

120. Henkel, H.G. and Ebing, W. "A Contribution to the Gas Chromatography of Triazine Herbicides," J. of G.C., July, 1964.

121. Hersey, J. "Choosing a Solvent for Insecticide Formulations," Farm Chemicals, 129 (10) (October, 1966).

122. Hill, D.W. and McCarty, P.L. "Anaerobic Degradation of Selected Chlorinated Hydrocarbon Pesticides," J. WPCF, 39 (8) (Aug., 1967).

123. Hindin, Ervin, et al. Collection and Analysis of Synthetic Organic Pesticides from Surface and Ground Water, Sanitary Engineering Section of the Division of Industrial Research, Washington State University, Pullman, Washington.

124. Holden, A.V., et al. "The Examination of Surface Waters and Sewage Effluents for Organo-Chlorine Pesticides," J. Proc. Inst. Sew. Purif., (1966).

125. Honea, F.I., et al. "Pesticides Industry," Task Report, MRI, Kansas City, Mo. 64110, (June 25, 1975), EPA Contract No. 68-02-1324, MRI Project No. 3821-C-28.

126. Horrobin, S. "The Hydrolysis of Some Chloro-1,3,5-Triazines: Mechanism: Structure and Reactivity," J. Chem. Soc., (1963), England.

127. Hosler, C.F., Jr. "Degradation of Zectran in Alkaline Water," Bulletin of Environmental Contamination and Toxicology, Vol. 12, No. 5, Springer-Verlag, New York, Inc, 1974.

128. Howard, P.H., Jaxena, J., Durkin, P.R., and Ou, L.T. Review and Evaluation of Available Techniques for Determining Persistence and Routes of Degradation of Chemical Substances in the Environment, U.S. EPA, Office of Toxic Substances, EPA-560/5-75-006, May, 1975.

129. Huang, J.C., "Organic Pesticides in the Aquatic Environment," Water and Sewage Works, 118 (5) (1971).

130. Huang, J.C. and Liao, C.S. "Adsorption of Pesticides by Clay Minerals," J. San. Eng. Div., ASCE, 96 (SA5) (1970).

131. Hutchins, R.A. "Activated Carbon-Economic Factors in Granular Carbon Thermal Regeneration," Chemical Engineering Progress, Vol. 69, No. 11, November, 1973.

132. Hutchins, R.A. "New Method Simplifies Design of Activated-Carbon Systems," Chemical Engineering, August 20, 1973.

133. I.C.I. America, Inc. "Evaluation of Granular Activated Carbon in Columns for Wastewater Treatment," Pollution Control Review, May, 1972.

134. I.C.I. America, Inc. Evaluation of Granular Carbon for Chemical Process Applications, Pollution Control Review, May, 1975.

135. I.C.I. America, Inc. A Symposium on Activated Carbon, 1968.

136. I.C.I. United States, Inc. "Adsorption Isotherm of Granular Carbon for Wastewater," Pollution Control Review, May, 1972.

137. I.C.I. United States, Inc. Gro-Safe Activated Charcoal References, Specialty Chemical Division, Wilmington, Delaware 19897.

138. Ingols, R.S., et al. "Biological Activities of Halophenols," JWPCF, 38 (4) (April, 1966).

139. Iowa State University Department of Industrial Engineering and Engineering Research Institute. "Estimating Staff and Cost Factors for Small Wastewater Treatment Plants Less Than 1 MGD," Parts I and II, EPA Grant No. 5P2-WP-195-0452, June, 1973.

140. Iowa State University Department of Industrial Engineering and Engineering Research Institute. Staffing Guidelines for Conventional Wastewater Treatment Plants Less Than 1 MGD," EPA Grant No. 5P2-WP-195-0452, June, 1973.

141. Jernign, W.M., Georgia Department of Natural Resources. Letter from, to G. Jett, December 17, 1976.

142. Johnson, D.P. and Stansbury, H.A., Jr. "Determination of Temik Residues in Raw Fruits and Vegetables," J. Assoc. Off. Anal. Chem., 49(2):399 (1969).

143. Johnson, O. "CW Report: Pesticides '72 Part 1 and Part 2," Chemical Week, (June 21, 1972), Part II (July 26, 1972).

144. Joiner, R.L., et al. "Comparative Inhibition of Boll Weevil, Golden Shiner, and White Rat Cholinesterases by Selected Photoalteration Products of Parathion," Pesticide Biochemistry and Physiology, 2(4), Academic Press, Inc., Jan., 1973.

145. Jones, G.E., Dubey, H.D., and Freeman, J.F. "Persistence of Diphenamid in Tobacco Field Soils," Weeds, 12, 313 (1964).

146. Kane, P.F., et al. "Assay of Co-Ralin Technical Material and Formulated Products," Agricultural and Food Chemistry, Vol. 8, No. 1, Jan-Feb, 1960.

147. Karinen, J.F., Lamberton, J.G., Stewart, N.E., and Terriere, L.C. "Persistence of Carbaryl in the Marine Estuarine Environment. Chemical and Biological Stability in Aquarium Systems," J. Agr. Food Chem., Vol. 15, No. 1, (1967).

148. Kearney, P.C. and Kaufman, D.D. Degradation of Herbicides, Marcel Dekker, Inc., New York, 1969.

149. Kearney, P.C. and Kaufman, D.D., editors. Herbicides, Chemistry, Degradation, and Mode of Action, 2nd Edition, Vols. 1 and 2, Marcel Dekker, Inc., New York and Basel, 1975.

150. Kennedy, D.C. "Treatment of Effluent from Manufacture of Chlorinated Pesticides with a Synthetic, Polymeric Adsorbent, Amberlite XAD-4," Envir. Sci. & Tech., 1(2) (Feb. 1973).

151. Kennedy, M.V., et al. "Chemical and Thermal Methods for Disposal of Pesticides," Residue Reviews, 29 (1969).

152. Kent, J.A., editor. Reigel's Industrial Chemistry, 7th Edition, Reinhold Publishing Corporation, New York, 1974.

153. Kerr McGee Chemical Corporation and Engineering Science, Inc. A Preliminary Engineering Report on Wastewater Treatment and Systems Improvement, Hamilton, Miss., 1975.

154. Khan, S.V., Greenhalgh, R., and Cochrane, W.P. "Chemical Derivatization of Hydroxyatrazine for Gas Chromatographic Analysis," Agricultural and Food Chemistry, Vol. 23, No. 3, May/June, 1975.

155. Kimbrough, R.D. "Review of the Toxicity of Hexachlorophene, Including Its Neurotoxicity," The Journal of Clinical Pharmacology, 13(11/12), Fort Orange Press, New York, Nov./Dec., 1973.

156. Kimbrough, R.D. "Toxic Effects of the Herbicide Paraquat," Chest, Vol. 65 (Supplement) (April, 1974).

157. King, P.H., et al. Bulletin 32, Removal of Selected Contaminants from Water by Sorption of Coal, Clearing House, Washington, 1969.

158. Kirk-Othmer. Encyclopedia of Chemical Technology, 2nd Edition, Interscience Publishers Division, John Wiley and Sons, Inc.

159. Knuesli, E., Berrer, D., Dupuis, G., and Esser, H. Chapter 2, S-Triazines in Degradation of Herbicides, Edited by P.C. Kearney and D.D. Kaufman, Marcel Dekker, Inc., New York, 1969.

160. Konrad, J.G. and Chesters, G. "Degradation in Soils of Ciodrin and Organophosphorus Insecticides," J. Agr. Food Chem., 17(2):226-230 (March-April, 1969).

161. Konrad, J.G., Chesters, G., and Armstrong, D.E. "Soil Degradation of Malathion, A Phosphorodithioate Insecticide," Soil Sci. Soc. Amer. Proc., 33, 259 (1969).

162. Kozlorowski, B. and Kucharski, J. Industrial Waste Disposal, Pergamon Press, New York, 1972.

163. Kutz, F.W., et al. "Mirex Residues in Human Adipose Tissue," Environmental Entomology, 3(5) (Oct. 1974).

164. Kutz, F.W., et al. "The National Human Monitoring Program for Pesticides," Laboratory Investigation, International Academy of Pathology, 30(3) (1974).

165. Kutz, F.W., et al. "Pesticide Residues in Adipose Tissue of the General Population of the U.S., FY 1970 Survey," The Bulletin of the Society of Pharmacological and Environmental Pathologist, 11(3) (Sept. 1974).

166. LaForge, F.B., et al. "Dimerized Cyclopentadienones from Esters of Allethrolone," J. Am. Chem. Soc., Vol 74 (1952).

167. Lambden, A.E. and Sharp, D.H. "Treatment of Effluent from the Manufacture of Weedkillers and Pesticides," Manufacturing Chemist, 31:198-201, May 1970.

168. Lanquette, K.H. and Paulson, E.G. "Treatment of Heavy Metals in Wastewater," Pollution Engineering, October 1976.

169. Lawless, E.W., et al. Guidelines for the Disposal of Small Quantities of Unused Pesticides, MRI, Kansas City, Mo., EPA-670/2-75-057, EPA-6801-0098, PB-244557/5GA, (June, 1975).

170. Lawless, E.W., et al. The Pollution Potential in Pesticide Manufacture, U.S. EPA Technical Studies Report TS-00-72-04 (June 1972).

171. Lawless, E.W., et al. "Production, Distribution, Use and Environmental Impact Potential of Selected Pesticides," Midwest Research Institute, Kansas City, Missouri (Feb. 1973-Mar. 1974).

172. Leigh, G.M. "Degradation of Selected Chlorinated Hydrocarbon Insecticides," JWPCF, 41(11), Part 2 (Nov. 1969).

173. Leshendok, Thomas V. Hazardous Waste Management Facilities in the United States, EPA 530-SW-146.2, U.S. EPA, February, 1976.

174. Liang, T.T. and Lichtenstein, E.P. "Synergism of Insecticides by Herbicides: Effect of Environmental Factors," Science, 186, 1974.

175. Lindner, G. and Nyberg, K. Environmental Engineering, A Chemical Engineering Discipline, D. Reidel Publishing Company, Boston, Mass. 02116, 1973.

176. Linder, R.E., et al. "The Effect of Polychlorinated Biphenyls on Rat Reproduction," Fd. Cosmet. Toxicol., Vol. 12, Pergamon Press, 1974.

177. Liptak, B.G., editor. Environmental Engineers' Handbook, Volume I, Water Pollution, Chilton Book Company, Radnor, Pa., 1974.

178. Loos, et al. "Phenoxyacetate Herbicide Detoxication by Bacterial Enzymes," J. of Agr. and Food Chem., 15(5) (Oct. 1967).

179. Mackay, D. and Wolkoff, A.W. "Rate of Evaporation of Low-Solubility Contaminants from Water Bodies to Atmosphere," Envir. Sci. & Tech. 7(7) (July 1973).

180. Mahlock, J.L. Program Report on Chemical Fixation of Hazardous Waste and Air Pollution-Abatement Sludges, for EPA, January, 1975.

181. Malin, H.M., Jr. "Cities Treat Industrial Process Wastes," Env. Science and Tech., 5(10), Oct. 1971.

182. Mann, J.B., et al. "Development of Sampling and Analytical Procedure for Determining Hexachlorobenzene and Hexachloro-1, 3-butadiene in Air," Environmental Science & Technology, Vol. 8, American Chemical Society (June 1974).

183. Manufacturing Chemists Association, Inc. Guidelines for Chemical Plants in the Prevention, Control and Reporting of Spills, Washington, D.C., 1972.

184. Manufacturing Chemists Association. Laboratory Waste Disposal Manual, 2nd Edition, September 1969 (1st Edition published June 1969).

185. Marks, D.R. "Chlorinated Hydrocarbon Pesticide Removal from Waste Water," Velsicol Chemical Corporation (EPA Demonstration Grand 803159-01).

186. Marquardt Company. Report on the Destruction of "Orange" Herbicide by Incineration, for U.S. Air Force, Environmental Health Laboratory, Kelly Air Force Base, Texas, February 1974.

187. Martin, H. and Worthing, C.R. Pesticide Manual, British Crop Protection Council, 1972.

188. Martin, J.D., et al. "Waste Stabilization Experiences at Union Carbide, Seadrift, Texas, Plant."

189. Matsumura, Fumio, et al. Environmental Technology of Pesticides, Academic Press, New York, New York, 1972.

190. Mason, Thomas J., Ph.D., et al. Atlas of Cancer Mortality for U.S. Counties: 1950-1969, DHEW Pub. No. (NIH) 75-780, U.S. Department of Health, Education, and Welfare, National Institute of Health, Bethesda, Maryland 20014.

191. McDermott, G.N. "Industrial Spill Control and Pollution Incident Prevention," J. Water Pollution Control Federation, 43(8):1629, (1971).

192. McKee, J.E. and H.W. Wolf. "Water Quality Criteria," 2nd ed., California Water Resources Board, 1971.

193. Medical College of Ohio at Toledo. "Report of the Mercury Advisory Committee of the Environmental Protection Agency to the Administrator," July 6, 1971.

194. Melnikov, N.N. Chemistry of Pesticides, Springer-Verlag, New York, 1971.

195. Metcalf, R.L. Organic Insecticides, Interscience Publishers, New York (1955).

196. Metcalf, R.L., Fukuto, T.R., Collins, C., Borck, K., El-Aziz, S.A., Mumoz, R. and Cassil, C.C. "Metabolism of 2,2-Dimethyl-2,3Dihydrobenzofuranyl-7-N-Methylcarbamate (Furadan) in Plants, Insects, and Mammals," J. Agr. Food Chem., 16(2):300-311 (1968).

197. Metcalf, R.L., et al. "Model Ecosystem for the Evaluation of Pesticide Biodegradability and Ecological Magnification," Environmental Science and Technology, 5(8) (August, 1971).

198. Metcalf, R.L. and Fukuto, T.R. "Toxic Action of Dipterex and DDVP to the House Fly," Journal of Economic Entomology, Vol. 52, No. 1, February, 1959.

199. Mick, D.L., et al. "Organochlorine Insecticide Residues in Carpeting," Pesticides Monitoring Journal, 8(2) (September, 1974).

200. Midwest Research Institute. "Aldrin/Dieldrin," Wastewater Management Review No. 1, for U.S. EPA, Hazardous and Toxic Substances Regulation Office, May, 1974.

201. Midwest Research Institute. "Endrin," Wastewater Management Review No. 2, for U.S. EPA, Hazardous and Toxic Substances Regulation Office, May, 1974.

202. Midwest Research Institute. Identification of Organic Compounds in Organophosphorus Pesticide Manufacturing Wastewater, Quarterly Report No. 1, for Dr. Arthur W. Garrison, January 5, 1976.

203. Midwest Research Institute. Identification of Organic Compounds in Organophosphorus Pesticide Manufacturing Wastewater, Quarterly Report No. 2, for Dr. Arthur W. Garrison, June 23, 1976.

204. Midwest Research Institute. Inventory and Environmental Effects of Industrial and Governmental Pesticide Uses, for U.S. EPA, Office of Water Programs, April, 1972.

205. Midwest Research Institute. "Toxaphene," Wastewater Management Review No. 3, for U.S. EPA, Hazardous and Toxic Substances Regulation Office, May, 1974.

206. Midwest Research Institute. "Wastewater Treatment Technology Documentation for Aldrin/Dieldrin, Endrin, DDT and Toxaphene," for U.S. EPA, Office of Water Planning and Standards, July, 1975.

207. Midwest Research Institute. Wastewater Treatment Technology Documentation for Aldrin/Dieldrin Manufacture and Formulation, Final Report Feb. 6, 1976, Contract No. 68-01-3524, MRO Project No. 4127-C.

208. Midwest Research Institute. Wastewater Treatment Technology Documentations for DDT, Manufacture and Formulation, Final Report, Feb. 6, 1976, Contract No. 68-01-3524, MRI Project No. 4127-E.

209. Midwest Research Institute. Wastewater Treatment Technology Documentation for Endrin, Manufacture and Formulation, Final Report, Feb. 6, 1976, Contract No. 68-01-3524, MRI Project No. 4127-C.

210. Midwest Research Institute. Wastewater Treatment Technology Documentation, for Toxaphene, Manufacture and Formulation, Final Report, Feb. 6, 1976, Contract No. 68-01-3524, MRI Project No. 4127-C.

211. Miller, F.M. and Gomes, E.D. "Detection of DCPA Residues in Environmental Samples," Pesticides Monitoring Journal, 8, (1) (June, 1974).

212. Mills, R.E. "Development of Design Criteria for Biological Treatment of 2,4-D Wastewater," Canadian J. of Chemical Engineering, 37 (55) (Oct., 1959).

213. Minear, R.A. and Patterson, J.W. Wastewater Treatment Technology, 2nd Edition, State of Illinois Institute for Environmental Quality, January, 1973.

214. Miranowski, J.A., et al. "Crop Insurance and Information Services to Control Use of Pesticides," Socioeconomic Environmental Studies Series (September, 1974), EPA-600/5-74-018.

215. Moore, F.L., et al. "Recovery of Toxic Metals From Industrial Effluent Solutions by Solvent Extraction," Ecology and Analysis of Trace Contaminants, Progress

Report January 1973 - September 1973, Oak Ridge National Laboratory. ORNL-NSF-EATC-6.

216. Mounce, L.M. and Savage, E.P. "The Epidemiology of Aerial Application Accidents in the High Plains 1966-1969," *Agricultural Aviation*, *15* (4) (October, 1973).

217. Moyer, J.R. and Parmele, C.S. "Demonstration of Ultraviolet Chlorination of Organic Acids in Waste Brines," EPA Project 500300, Environmental Research Lab., Athens, GA, 30601.

218. Muhlmann, R. and G. Schrader. "Hydrolyse der Insektiziden Phosphorsaureester," *Z. Naturforsch.*, 12b, 196 (1957) (German Publication).

219. National Environmental Research Center. "Evaluation of Hazardous Waste Emplacement in Mined Openings," NERC Contract No. 68-03-0470, September, 1974.

220. Nemerow, N.L. *Liquid Waste of Industry - Theories, Practices, and Treatment*, Addison-Wesley Publishing Company, Reading, Mass., 1971.

221. Newland, W., *et al*. "Degradation of -BHC in Simulated Lake Impoundments as Affected by Aeration," *J.WPCF*, *41* (5) (1969).

222. "New Weapons Against Insects," *Chemical and Engineering News*, July 28, 1975.

223. Nicholson, H.P. "Insecticide Pollution of Water Resources," *J.AWWA*, *51* (8) (1959).

224. Novak, S.M. "Biological Waste Stabilization Ponds at Exxon Company, U.S.A. Baytown Refinery and Exxon Chemical Company, U.S.A. Chemical Plant (Divisions of Exxon Corporation) Baytown, Texas."

225. Obien, S.R. and Green, R.E. "Degradation of Atrazine in Four Hawaiian Soils," *Weed Science*, *17*:509, 1969.

226. O'Kelley, J.C. and Deason, T.R. "Degradation of Pesticides by Algae," U.S. EPA Grant No. R800371, EPA-600/3-76-022, March, 1976.

227. Otakie, G.F. *A Guide to the Selection of Cost-Effective Wastewater Treatment Systems*, EPA-430/9-75-002,

Technical Report, U.S. EPA, Office of Water Program Operations, Washington, D.C. 20460.

228. Packer, K. *Nanogen Index*, a dictionary of pesticides and chemical pollutants, Nanogens International, Freedom, CA, 1975.

229. Pape, B.E. and Zabik, M.J. "Photochemistry of Bioactive Compounds. Solution-Phase Photochemistry of Symmetrical Triazines," *J. Agr. Food Chem.*, *20*(2), 1972.

230. Pape, B.E. and Zabik, M.J. "Photochemistry of Selected 2-Chloroand 2-Methylthio-4,6-di(Alkylamino)-S-Triazine Herbicides," *J. Agr. Food Chem.*, Vol. 18, No. 2, 1970.

231. Paris, D.F. and Lewis, D.L. "Chemical and Microbial Degradation of Ten Selected Pesticides in Aquatic Systems," *Residue Reviews*, 45:95-124 (1973).

232. Paris, D.F., *et al*. *Microbial Degradation and Accumulation of Pesticides in Aquatic Systems*, EPA Office of Research and Development (March, 1975), EPA-660/3-75-007.

233. Parker, W.P. *Wastewater Systems Engineering*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1975.

234. Patterson, J.W., Ph.D. "State-of-the-Art for the Inorganic Chemicals Industry: Inorganic Pesticides," U.S. EPA, Office of Research and Development, EPA-600/2-74-009a, March, 1975.

235. Peltier, B., *et al*. "Biological Investigation of Stauffer Chemical Company (Organic Plant)," (trip report on January 24-30, 1975, investigation), U.S. EPA, NERC, Athens, Georgia.

236. Perry, J.H. *et al*. *Chemical Engineer's Handbook*, 5th Edition, McGrawHill Book Company, New York, N.Y., 1973.

237. *Pesticide Handbook - Entoma*, Entomological Society of America, 24th Edition, 1974.

238. "Pesticides '72," *Chemical Week*, Part 1, June 21, 1972.

239. Pittsburgh Activated Carbon. *The Laboratory Evaluation of Granular Activated Carbons for Liquid Phase Applications*, Division of Calgon Corp., Pittsburgh, PA 15230.

240. Piver, W.T. "Organotin Compounds: Industrial Applications and Biological Investigation," *Environmental Health Perspectives* (June, 1973).

241. Plimmer, J.R. "The Photochemistry of Halogenated Herbicides," *Residue Rev.*, *33*(47), 1971.

242. Posey, F.A. and Palko, A.A. "Electrochemical Recovery of Reducible Inorganic Pollutants from Aqueous Streams," *Ecology and Analysis of Trace Contaminants*, Progress Report January 1973 - September 1973, Oak Ridge National Lab., ORNL-NSF-EATC-6.

243. Pryor, W.A. and Smith K. "The Viscosity Dependence of Bond Homolysis. A Qualitative and Semiquantitative Test for Cage Return," *J. of Amer. Chem. S.*, *92*:(18), Sept. 9, 1970.

244. Quirk, T.P. "Application of Computerized Analysis of Comparative Costs of Sludge Dewatering by Vacuum Filtration and Centrifugation," *Proc., 23rd Industrial Waste Conference*, Purdue University, 1968, pp. 69-709.

245. Rabson P. and Plimmer, J.R. "Photoalteration of Pesticides: Summary of Workshop," *Science*, Vol. 180, 1973.

246. Reimold, Robert J., *et al*. *The Effects of Toxaphene Contamination on estuarine Ecology*, University of Georgia, Marine Institute, Sapelo Island, Georgia, September, 1973.

247. Reimold, Robert J. *Toxaphene Interactions in Estuarine Ecosystems*, University of Georgia, Marine Institute, Sapelo Island, Georgia, September, 1974.

248. Riley, B.T., Jr. *The Relationship Between Temperature and the Design and Operation of Biological Waste Treatment Plants*, submitted to the Effluent Guidelines Division, EPA, April, 1975.

249. Rinehart, T.M. *A Symposium on Activated Carbon*, ICI America, Inc., 1968.

250. Rizzo, J.R. and Shepherd, A.R. "Treating Industrial Wastewater with Activated Carbon," *Chemical Engineering*, January 3, 1977.

251. Rizzo, J.L. Use of Granular Activated Carbon for Industrial Wastewater Treatment, for 48th Annual Meeting of the Ohio Water Pollution Control Conference, Toledo, Ohio, June 12-14, 1974.

252. Robeck, G.G., et al. "Effectiveness of Water Treatment Process in Pesticide Removal," J.AWWA, 57, (8) (Feb., 1965).

253. Rose, A. and Rose, E. The Condensed Chemical Dictionary, 6th Edition, Reinhold Publishing Corporation, New York, 1961.

254. Ross, R.T. and Biros, F.J. "A Study of Intermolecular Complexes of BIS (p-Chlorophenyl) Acetic Acid and Some Biologically Significant Compounds," Mass Spectrometry and NMR Spectroscopy in Pesticide Chemistry, Plenum Publishing Corp., New York, N.Y.

255. Ross, R.T. and Gonzalez, J.G. "Short Communication," Analytica Chimica Acta., Vol. 70, Elsevier Scientific Publishing Co., Amsterdam, 1974.

256. Roy F. Weston, Inc. Draft Development Document for Effluent Limitations Guidelines and Standards of Performance - Organic Chemicals Industry, Phase II, U.S. EPA Office of Air and Water Programs, Effluent Guidelines Division, Washington, D.C. 20460, February, 1974.

257. Ruckelshaus, William D. "Report of the Mirex Advisory Committee," report to Administrator of EPA, Revised, March 1, 1972.

258. Rudolfs, W. Industrial Wastes, Their Disposal and Treatment, Reinhold Publishing Corporation, New York, 1953.

259. Rumker, V.R., et al. "The Search for Safer, More Selective, and Less Persistent Pesticides," Bioscience, 20 (18) (September, 1970).

260. Rumker, V.R., et al. The Use of Pesticides in Suburban Homes and Gardens and Their Impact on the Aquatic Environment, EPA, Office of Water Programs, Applied Tech. Div., Rural Waste Branch, Pesticide Study Series 2 (May, 1972).

261. Rumker, R. and F. Horay. *Pesticide Manual*, Vol. I., Department of State, Agency for International Development (1972).

262. Ruzo, L.D., *et al*. "Photochemistry of Bioactive Compounds. Kinetics of Selected S-Triazines in Solution, *J. Agr. Food Chem.*, *21*, (6), 1973.

263. Saldick, J. *Biological Treatment of Plant Waste Streams to Remove Cyanuric Acid*, U.S. Patent 3,926,795, December 16, 1975.

264. Saleh, F. Monthly Report Dallas, Texas, Advanced Waste Treatment Plant, May, 1973.

265. Sanborn, J.R. "The Fate of Select Pesticides in the Aquatic Environment," *Ecological Research Series*, (December, 1974) EPA-660/3-74-025.

266. Sax, N.I. *Dangerous Properties of Industrial Material*, 4th Edition, Van Nostrand, Reinhold Company, New York, 1975.

267. Schacht, R.A. "Pesticides in the Illinois Waters of Lake Michigan," *Ecological Research Series*, (January, 1974) EPA-660/3-74-002.

268. Seiber, J.N., *et al*. "Determination of Pesticides and Their Transformation Products in Air," *Environmental Dynamics of Pesticides*, Plenum Publishing Corp., New York, N.Y.

269. Sherma, J. and Shafik, T.M. "A Multiclass, Multiresidue Analytical Method for Determining Pesticide Residue in Air," *Archives of Environmental Contamination and Toxicology*, *3* (1), Springer-Verlag New York, Inc., 1975.

270. Shreve, R.N. *Chemical Process Industries*, 3rd Edition, McGraw-Hill, New York, 1967.

271. Sigworth, E.A. "Identification and Removal of Herbicides and Pesticides," *J.AWWA* 57 (8), August, 1965.

272. Sittig, M. *Pesticides Production Processes*, Noyes Development Corporation, Park Ridge, New Jersey, 1967.

273. Skipper, H.D., Gilmour, C.M., and Furtick, W.R. "Microbial Versus Chemical Degradation of Atrazine in Soils," Soil Sci. Soc. Amer. Proc., Vol. 31, 1967.

274. Skipper, H.D., Volk, V.V. and Frech, R. "Hydrolysis of a Chloro-s-Triazine Herbicide," J. Agric. Food Chem., 24 (1) (1976).

275. Smith, R. "Cost of Conventional and Advanced Treatment of Wastewater," J.WPCF, 40 (9) (1968).

276. Spencer, D.A. "Trends in Pesticide Use," Env. Science and Tech., 4 (6) (June, 1970).

277. Spencer, E.Y. Guide to the Chemical Used in Crop Protection, 5th Edition, Research Branch, Canada Department of Agriculture, Publication 1093, February, 1968, Information Canada, Ottawa, Canada.

278. Spiller, D. "A Digest of Available Information on the Insecticide Malathion," Adv. Pest Control Research, 4,249 (1961).

279. Starr, H.G., et al. "Contribution of Household Dust to the Human Exposure to Pesticides," Pesticides Monitoring Journal, 8 (3) (Dec., 1974).

280. Stecher, P.G., editor. The Merck Index, An Encyclopedia of Chemicals and Drugs, 8th Edition, Merck and Company, Inc., Rahway, New Jersey, 1968.

281. Stevens, J.I. "The Roles of Spillage, Leakage and Venting in Industrial Pollution Control," presented at Second Annual Environmental Engineering and Science Conference, University of Louisville, April, 1972.

282. Stutz, C.N. "Treating Parathion Wastes," Chemical Engineering Progress, Vol. 62, No. 10, October, 1966.

283. Swanson, C.L. "Unit Process Operating and Maintenance Costs for Conventional Waste Treatment Plants," FWQA, Cincinnati, Ohio, June, 1968.

284. Sweeney, K.H. "Chlorinated Hydrocarbon Pesticide Removal From Wastewater," Envirogenics Systems Company, EPA Demonstration Grant 803159-01.

285. Sweeney, K.H., et al. Development of Field Applied DDT, (May, 1974), EPA-660/2-74-036, Washington, D.C.

286. Thompson, J.F. Analysis of Pesticide Residue in Human and Environmental Samples, U.S. EPA (December, 1974).

287. Thompson, J.F. Analytical Reference Standards and Supplemental Data for Pesticides and Other Organic Compounds, U.S. EPA, Office of Research and Development (May, 1976), EPA-600/9-76-012.

288. Tiedje, J., Duxbury, J., Alexander, M., and Dawson, J. "2,4-D Metabolism: Pathway of Degradation of Chlorocatechols by Arthrobacter, sp.," J. Agri. Food Chem., 17 (5), Sept.-Oct., 1969.

289. Tomkiewicz, M., et al. "Electron Paramagnetic Resonance Spectra of Semiquinone Intermediates Observed during the Photo-oxidation of Phenol in Water, J. Amer. Chem. S., 93(25), Dec. 15, 1971.

290. Toy, A.D.F. "Preparation and Properties of Some Unsymmetrica Tetraakyl Pyrophosphates," J. Am. Chem. Soc., Vol. 72, 1950.

291. Toy, A.D.F. "The Preparation of Tetraethyl Pyrophosphate and Other Tetralkyl Pyrophosphates," J. Am. Chem. Soc., Vol. 70, 1948.

292. Trecker, D.J., et al. "Photochemistry of Aryl Carbamates," Chemical Communications, pp. 1034-1035, 1968.

293. TRW Systems. Recommended Methods of Reduction, Neutralization, Recovery, or Disposal of Hazardous Waste, Vol V, National Disposal Site Candidate Waste Stream Constituent Profile Reports - Pesticides and Cyanide Compounds, U.S. EPA, Office of Research and Development, August, 1973.

294. Union Carbide Corp., Chemical and Plastics Physical Properties, 1975-1976 Edition, New York, N.Y.

295. Union Carbide Corp. Experimental Procedure for Obtaining Data Required for Sizing Liquid Absorption Systems Using Granular Carbon, Carbon Products Division, New York.

296. U.S. Congress. Public Law 92-500, 92nd Congress, S.2770, October 18, 1972.

297. U.S. Department of the Army. Thermal Degradation of Military Standard Pesticide Formulations, TPW Report #24768-6018-RV-00, U.S. Army Medical Research and Development Command, Washington, D.C., December, 1974.

298. U.S. Department of Health, Education, and Welfare. "Interaction of Heavy Metals and Biological Sewage Treatment Processes," Environmental Health Series, HEW Office of Water Supply and Pollution Control, Washington, D.C., May, 1965.

299. U.S. Department of Health, Education, and Welfare. Report of the Secretary's Commission on Pesticides and Their Relationship to Environmental Health, Part I and II, December, 1969.

300. U.S. Department of the Interior. "Cost of Clean Water," Industrial Waste Profile No. 3, Dept. of Int. GWQA, Washington, D.C., November, 1967.

301. U.S. Department of Interior. Metabolism of Pesticides, Washington, D.C., July, 1969.

302. U.S. Department of the Interior. "Phenolic Waste Reuse by Diatomite Filtration," Water Pollution Control Research Series, 12980EZF09/70, Federal Quality Administration, Washington, D.C., September, 1970.

303. U.S. Department of the Interior. Report on Insecticides in Lake Michigan, Pesticide Committee of the Lake Michigan Enforcement Conference, Great Lakes Region, November, 1968.

304. U.S. Department of the Interior, Fish and Wildlife Service. The Effects of Pesticides on Fish and Wildlife, Circular 226, Washington, D.C., August, 1965.

305. U.S. EPA. "Biological Treatment of Chlorophenolic Wastes," Water Pollution Control Research Series, (12130EGK 06/71), June, 1971.

306. U.S. EPA. "A Catalog of Research in Aquatic Pest Control and Pesticide Residues in Aquatic Environments," Pesticide Study Series - 1.

307. U.S. EPA. Compilation of Municipal and Industrial Injection Wells in the United States, EPA 520/9-74-020, Vol. I and II, EPA, Washington, D.C. 20460, 1974.

308. U.S. EPA. Control of Hazardous Material Spills, Proceedings of the 1972 National Conference on Control of Hazardous Material Spills, University of Texas, March, 1972.

309. U.S. EPA. Correspondence between ESE and N.L. Wolfe, Washington, D.C.

310. U.S. EPA. Degradation of Pesticides by Algae, EPA No. 600/3-76-022, Environmental Research Laboratory, Athens, Georgia, March, 1976.

311. U.S. EPA. Development Document for Effluent Limitations Guidelines and Standards of Performance, draft, Organic Chemicals Industry Phase ii, Contract No. 68-01-1509, February, 1974.

312. U.S. EPA. Development Document for Interim Final Effluent Limitations Guidelines for the Pesticide Chemicals Manufacturing, Point Source Category, EPA 440/1-75/060d, November, 1976.

313. U.S. EPA. "Draft Development Document for Interim Final Effluent Limitations, Guidelines and Standards of Performance of the Miscellaneous Chemicals Manufacturing Point Source Category," Supplement A and B, Washington, D.C. 20460, February, 1975.

314. U.S. EPA. "Effective Hazardous Waste Management (Non-Radioactive)," Federal Register, Part II, Vol. 41, No. 161, August 18, 1976, pp. 35050-35051.

315. U.S. EPA. Effects of Pesticides in Water, a report to the States, EPI.2:P43/2.

316. U.S. EPA. "Effluent Guidelines and Standards, General Provisions," Federal Register, Part II, Vol. 39, No. 24, pp. 4531-4533, February 4, 1974.

317. U.S. EPA. The Federal Insecticide, Fungicide, and Rodenticide Act, As Amended, Public Law 94-140, November 28, 1975.

318. U.S. EPA. Final Report of the Task Force on Excess Chemicals, June 29, 1973.

319. U.S. EPA. "Flow Equalization," U.S. EPA Technology Transfer, EPA, Washington, D.C. 20460, May, 1974.

320. U.S. EPA. Guidelines for the Disposal of Small Quantities of Unused Pesticides, MRI Contract 68-01-0098, Project 15090 HGR, Published by MRI, Kansas City, MO 64110.

321. U.S EPA. "Guidelines for Registering Pesticides in United States," Federal Register, Part II, Vol. 40, No. 123, pp. 26802-26928, June 25, 1975.

322. U.S. EPA. "Handbook for Analytical Quality Control in Water and Wastewater Laboratories," U.S. EPA Technology Transfer, Washington, D.C. 20460, June, 1972.

323. U.S. EPA. Herbicide Toxicity in Mangroves, EPA No. 600/3-76-004, Environmental Research Laboratory, Gulf Breeze, Florida 32561.

324. U.S. EPA. Information About Hazardous Waste Management Facilities, EPA 530/SW-145, July, 1975.

325. U.S. EPA. "Methods for Chemical Analysis of Water and Wastes," U.S. EPA Technology Transfer, EPA 625/6-74-003, Washington, D.C. 20460, 1974.

326. U.S. EPA. Methods for Organic Pesticides in Water and Wastewater, mental Research Center, Cincinnati, Ohio 45268, EP1.8:P43/2, April, 1972.

327. U.S. EPA. "Monitoring Industrial Wastewater," U.S. EPA Technology Transfer, Washington D.C. 20460, August, 1973.

328. U.S. EPA, Office of Air and Water Programs. Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Basic Fertilizer Chemicals Segment of the Fertilizer Manufacturing Point Source Category, EPA 440/1-73/011, November, 1973.

329. U.S. EPA, Office of Air and Water Programs. Development Document for Effluent Limitations Guidelines and Standards of Performance - Organic Chemicals Industry", EPA 440/1-74/009a, Effluent Guidelines Division, April, 1974.

330. U.S. EPA, Office of Air and Water Programs. Draft Development Document for Effluent Limitations Guidelines and Standards of Performance - Steam Supply and

Noncontact Coding Water Industries, Effluent Guidelines Division, October, 1974.

331. U.S. EPA, Office of Air and Water Programs. *Effluent Limitations Guidelines and Standards of Performance, Metal Finishing Industry*, Draft Development Document, EPA 440/1-75/040 and EPA 440/1-75/040a, Effluent Guidelines Division, Washington, D.C., April, 1975.

332. U.S. EPA, Office of Enforcement. *Report on an Investigation of Pesticide Pollution in the Lower Colorado River Basin - 1973*, National Field Investigations Center, Denver, Colorado, December, 1973.

333. U.S. EPA, Office of Enforcement. *South Dakota Toxaphene Use Study, June-September, 1975*, EPA/2-75-007, National Enforcement Investigations Center, Denver, Colorado, October, 1975.

334. U.S. EPA, Office of Enforcement. *Translocation of Heptachlor and Chlordane from Indiana Corn Fields*, EPA-330/9-75-002, National Enforcement Investigations Center, Denver, Colorado, September, 1975.

335. U.S. EPA, Office of Pesticide Programs. "Initial Scientific and Mini Economic Review of Aldicarb," *Substitute Chemicals Program*, EPA-540/1-75-013, May, 1975.

336. U.S. EPA, Office of Pesticide Programs. "Initial Scientific and Mini Economic Review of Bromacil," *Substitute Chemicals Program*, EPA-540/1-75-006, March, 1975.

337. U.S. EPA, Office of Pesticide Programs. "Initial Scientific and Mini Economic Review of Captan," *Substitute Chemicals Program*, EPA-540/1-75-012, April, 1975.

338. U.S. EPA, Office of Pesticide Programs. "Initial Scientific and Mini Economic Review of Carbofuran," *Substitute Chemicals Program*, EPA-540/1-76-009, July, 1976.

339. U.S. EPA, Office of Pesticide Programs. "Initial Scientific and Mini Economic Review of Malathion," *Substitute Chemicals Program*, March, 1975.

340. U.S. EPA, Office of Pesticide Programs,. "Initial Scientific and Mini Economic Review of Methyl Parathion," *Substitute Chemicals Program*, February, 1975.

341. U.S. EPA, Office of Pesticide Programs. "Initial Scientific and Mini Economic Review of Monuran," *Substitute Chemicals Program*, EPA-540/1-75-028, November, 1975.

342. U.S. EPA, Office of Pesticide Programs. "Initial Scientific and Mini Economic Review of Parathion," *Substitute Chemicals Program*, EPA-540/1-75-001, January, 1975.

343. U.S. EPA, Office of Pesticide Programs. "Initial Scientific Review of Cacodylic Acid," *Substitute Chemical Program*, EPA-540/1-75-021, December, 1975.

344. U.S. EPA, Office of Pesticide Programs. "Initial Scientific and Mini Economic Review of Croto Xyphos, *Substitute Chemical Program*, EPA-540/1-75-015, June 1972.

345. U.S. EPA, Office of Pesticide Programs. "Initial Scientific Review of MSMA/DSMA," *Substitute Chemical Program*, EPA-540/1-75-020, December, 1975.

346. U.S. EPA, Office of Pesticide Programs. *Substitute Chemical Program - Initial Scientific Review of PCNB*, EPA-540/1-75-016, April, 1976.

347. U.S. EPA, Office of Research and Development. "An Analysis of the Dynamics of DDT in Marine Sediments," *Ecological Research Series*, EPA-660/3-75-013, May, 1975.

348. U.S. EPA, Office of Research and Development. "Chlorinated Hydrocarbons in the Lake Ontario Ecosystem (IFY.GL)," *Ecological Research Series*, EPA-660/3-75-022, June, 1975.

349. U.S. EPA, Office of Research and Development. "A Conceptual Model for the Movement of Pesticides Through the Environment," *Ecological Research Series*, EPA-660/3-74-024, December, 1974.

350. U.S. EPA, Office of Research and Development. "A Conceptual Model for the Movement of Pesticides Through

the Environment," Ecological Researchseries, EPA-660/3-75-022, June, 1975.

351. U.S. EPA, Office of Research and Development. "Current Practices in G.C.-M.S. Analysis of Organics in Water," Environmental Protection Technology Series, EPA-R2-73-277, August, 1973.

352. U.S. EPA, Office of Research and Development. "Development of Treatment Process for Chlorinated Hydrocarbon Pesticide Manufacturing and Processing Wastes," Water Pollution Control Research Series, July, 1973.

353. U.S. EPA, Office of Research and Development. "The Effect of Mirex and Carbofuram on Estuarine Microorganisms," Ecological Research Series, EPA-660/3-75-024, June, 1975.

354. U.S. EPA, Office of Research and Development. Effect of Pesticides in Water.

355. U.S. EPA, Office of Research and Development. "Environmental Applications of Advanced Instrumental Analysis," Environmental Protection Technology Series, EPA-660/2-74-078, August, 1974.

356. U.S. EPA, Office of Research and Development. "Guidelines for the Disposal of Small Quantities of Unused Pesticides," Environmental Protection Technology Series, EPA-670/2-75-057, June, 1975.

357. U.S. EPA, Office of Research and Development. "Herbicide Runoff From Four Coastal Plain Soil Types," Environmental Protection Technology Series, EPA-660/2-74-017, April, 1974.

358. U.S. EPA, Office of Research and Development. "Methods for Acute Toxicity Tests with Fish, Macroinvertebrates, and Amphibians," Ecological Research Series, EPA 660/3-75-009, April, 1975.

359. U.S. EPA, Office of Research and Development. "The Occurrence of Organohalides in Chlorinated Drinking Waters," Environmental Monitoring Series, EPA-670/4-74-008, November, 1974.

360. U.S. EPA, Office of Research and Development. "Pesticides Movement from Cropland Into Lake Erie,"

Environmental Protection Technology Series, EPA-660/2-74-032, April, 1974.

361. U.S. EPA, Office of Research and Development. "Pesticide Transport and Runoff Model for Agricultural Lands," Environmental Protection Technology Series, EPA 660/2-74-013, December, 1973.

362. U.S. EPA, Office of Research and Development. "Pollution Control Technology for Pesticide Formulators and Packagers," Environmental Protection Technology Series, EPA-660/2-74-094, January, 1975.

363. U.S. EPA, Office of Research and Development. "Promising Technologies for Treatment of Hazardous Wastes," Environmental Protection Technology Series, EPA-670/2-74-088, November, 1974.

364. U.S. EPA, Office of Research and Development. "Radiation Treatment of High Strength Chlorinated Hydrocarbon Wastes," Environmental Protection Technology Series, EPA-660/2-75-017, June, 1975.

365. U.S. EPA, Office of Research and Development. "Specific Ion Mass Spectrometric Detection for Gas Chromatographic Pesticides Analysis," Environmental Protection Technology Series, EPA-660/2-74-004 January, 1974.

366. U.S. EPA, Office of Research and Development. Summation of Conditions and Investigations for the Complete Combustion of Organic Pesticides, EPA-5-03-3516A, February, 1975.

367. U.S. EPA, Office of Research and Development. "A Tissue Enzyme Assay for Chlorinated Hydrocarbon Insecticides," Environmental Protection Technology Series, EPA-660/2-73-027, May, 1974.

368. U.S. EPA, Office of Research and Development. Translation of Reports on Special Problems of Water Technology, Vol. 9, EPA-600/9-76-030, 1975.

369. U.S. EPA, Office of Research and Development. "Toxicity of Selected Pesticides to the Bay Mussel (Mytilus Edulis)," Ecological Research Series, EPA-660/3-75-016, May, 1975.

370. U.S. EPA, Office of Research and Development. "Use of Soil Parameters for Describing Pesticide Movement

Through Soils," Environmental Protection Technology Series, EPA-660/2-75-009, May, 1975.

371. U.S. EPA, Office of Research and Monitoring. "Liquid Chromatography of Carbonate Pesticides," Environmental Protection Technology Series, EPA-R2-72-079, October, 1972.

372. U.S. EPA, Office of Research and Monitoring. "Rapid Detection System for Organophosphates and Carbonate Insecticides in Water," Environmental Protection Technology Series, EPA-R2-72-010, August, 1972.

373. U.S. EPA, Office of Research and Monitoring. "Recondition and Reuse of Organically Contaminated Waste Sodium Chloride Brines," Environmental Protection Technology Series, EPA-R2-73-200, May, 1973.

374. U.S. EPA, Office of Toxic Substances. An Ecological Study of Hexachlorobenzene (HCB), Washington, D.C., April, 1976.

375. U.S. EPA, Office of Toxic Substances. Preliminary Assessment of Suspected Carcinogens in Drinking Water, Washington, D.C., December, 1975.

376. U.S. EPA, Office of Water and Hazardous Materials. Development Document for Interim Final Effluent Limitations, Guidelines, and Proposed New Source Performance Standards for the Pesticide Industry, Washington, D.C., July, 1976.

377. U.S. EPA, Office of Water Management. "The Use of Pesticides for Rangeland Sagebrush Control," Pesticide Study Series-3 (May 1972).

378. U.S. EPA, Office of Water Planning and Standards. Economic Analysis of Interim Final Effluent Guidelines for the Pesticides and Agricultural Chemicals Industry (Draft Report, Arthur D. Little, Inc., for EPA), EPA-230/1-76-065f.

379. U.S. EPA, Office of Water Programs. Development of a Case Study of the Total Effect of Pesticides on the Environment Non-Irrigated Croplands of the Midwest, Pesticide Study Series-4 (June, 1972), EP2.25:8.

380. U.S. EPA, Office of Water Programs. The Effects of Agricultural Pesticides in the Aquatic Environment,

Irrigated Croplands, San Jauquin Valley, P.S. Series-6 (June, 1972) EP2.25:8.

381. U.S.EPA, Office of Water Programs. Laws and Institutional Mechanisms Controlling the Release of Pesticides into the Environment Pesticide Study Series 11, U.S. Government Printing Office, 1972.

382. U.S.EPA, Office of Water Programs. The Movement and Impact of Pesticides Used in Forest Management on the Aquatic Environment in the Northeast, Pesticide Study Series-9 (July, 1972).

383. U.S. EPA, Office of Water Programs. Patterns of Pesticide Use and Reduction in Use as RElated to Social and Economic Factors, P.S. Series-10, 1972.

384. U.S.EPA, Office of Water Programs. Pesticides in the Aquatic Environment, EP2.2:P43/2, April 1972.

385. U.S.EPA, Office of Water Programs. Pesticide Usage and Its Impact on the Aquatic Environment in the Southeast, Pesticide Study Series-8 (September 1972), EP2.25:8.

386. U.S.EPA, Office of Water Program Operations. Pretreatment of Pollutants Introduced into publicly Owned Treatment Works, Washington, D.C. 20460, October 1973.

387. U.S.EPA, Office of Water Programs. The Use of Pesticides in Suburban Homes and Gardens and Their Impact on the Aquatic Environment, P.S. Series-2 (May 1972), EP2.25:8.

388. U.S.EPA, Office of Water Quality. "Investigation of Means for Controlled Self-Destruction of Pesticides," Water Pollution Control Research Series 88.89.90, ELO 06/70, June 1970.

389. U.S.EPA, Office of Water Quality. A Primer on Waste Water Treatment, 1974.

390. U.S.EPA, Organic Compounds, Identified in Drinking Water in the United States, Health Effects Research Laboratory, EPA, Cincinnati, Ohio, April 1, 1976.

391. U.S. EPA. "Oxygen Activated Sludge Wastewater Treatment Systems, Design Criteria and Operating Experience,"

U.S. EPA Technology Transfer, EPA, Washington, D.C. 20460, August, 1973.

392. U.S. EPA, Pesticides, Progress Report, Dec. 1970-June 1972, Washington, D.C., November 1972.

393. U.S. EPA, "Pesticides--EPA Proposal on Disposal and Storage," Part I, Federal Register, Vol. 39, No. 200, October 15, 1974.

394. U.S. EPA, "Pesticides and Pesticides Containers," Federal Register, Part IV, Vol. 39, No. 85 (Washington, D.C., May 1, 1976).

395. U.S. EPA. "Pesticide Products Containing Nitrosamines," Federal Register, Vol. 42, No. 37, February 24, 1977.

396. U.S. EPA, Pesticide Regulation Division. Acceptable Common Names and Chemical Names for the Ingredient Statement on Pesticides Labels, 2nd Edition, June 1972.

397. U.S. EPA. "Physical-Chemical Wastewater Treatment Plant Design," U.S. EPA Technology Transfer, EPA, Washington, D.C. 20460, August, 1973.

398. U.S. EPA. "The Pollution Potential in Pesticide Manufacturing," Pesticide Study Series-5, Technical Studies Report (T.S.-00-72-04) (June 1972).

399. U.S. EPA. "Procedural Manual for Evaluating the Performance of Wastewater Treatment Plants," U.S. EPA Technology Transfer, EPA Washington, D.C. 20460, October, 1973.

400. U.S. EPA, "Process Design Manual for Carbon Adsorption," U.S. EPA Technology Transfer, Washington, D.C., October 1976.

401. U.S. EPA. "Process Design Manual for Sludge Treatment and Disposal," U.S. EPA Technology Transfer, EPA 625/1-74-006, Washington, D.C. 20460, October, 1974.

402. U.S. EPA. "Process Design Manual for Suspended Solids Removal," U.S. EPA Technology Transfer, EPA 625/1-75-003a, Washington, D.C. 20460, January 1975.

403. U.S. EPA. "Process Design Manual for Upgrading Existing Waste Water Treatment Plants," U.S. EPA Technology Transfer, Washington, D.C. 20460, October 1974.

404. U.S. EPA. "Projects in the Industrial Pollution Control Division," Environmental Protection Technology Series, EPA 600/2-75-001, Washington, D.C., December 1974.

405. U.S. EPA. "Proposed Toxic Pollutant Effluent Standards," Federal Register, Vol. 38, No. 247, December 27, 1973.

406. U.S. EPA. "Quality Criteria for Water," EPA-440/9-76-023, September, 1976.

407. U.S. EPA. "A Quantitative Method for Toxaphene By GC-Cl-M Specific Ion Monitoring, EPA-600/4-76-010, Environmental Research Laboratory, Athens, Ga. 30601.

408. U.S. EPA, Report of Activated Carbon Jar Tests on Chemagro Wastewater, Surveillance and Analysis Division, Kansas City, Missouri, January 31, 1973.

409. U.S. EPA. Report of the Aldrin/Dieldrin Advisory Committee, to William D. Ruckelshaus, Administrator, EPA, March 28, 1972.

410. U.S. EPA. Report of the Amitrole Advisory Committee, March 12, 1971.

411. U.S. EPA. Report on Evaluation of Industrial Waste Discharges at Velsicol Chemical Company, Memphis, Tennessee, April 1972.

412. U.S. EPA. Report of the Lindane Advisory Committee, July 12, 1970.

413. U.S. EPA. "Residues of Organo-Chlorine Pesticides in Surface Waters," Water Pollution Control Notes--No. 36, (March, 1967).

414. U.S. EPA, Solid Waste Management Program. Assessment of Industrial Hazardous Waste Practices: Organic Chemicals, Pesticides, and Explosive Industries, Washington, D.C. 20460 (1967).

415. U.S. EPA. Spill Prevention Techniques for Hazardous Polluting Substances, OHM 7102001, Washington, D.C. 20460, February, 1971.

416. U.S. EPA. Tertiary Treatment of Combined Domestic and Industrial Wastes, EPA-R2-73-236, EPA, Washington, D.C. 20492, 1972.

417. U.S. EPA. "Variability in BOD Concentration from Biological Treatment Plant," Internal Memorandum, To: Lilliam Regelson, From: Charles Cook, March 1974.

418. U.S. EPA. "Wastewater Filtration Design Consideration," *U.S. EPA Technology Transfer*, EPA, Washington, D.C. 20460, July, 1974.

419. U.S. EPA. *Wastewater Sampling Methodologies and Flow Measurement Techniques*, EPA 907/9-74-005, EPA Surveillance and Analysis, Region VII, Technical Support Branch, June, 1974.

420. U.S. EPA, Working Group on Pesticides. "Ground Disposal of Pesticides: The Problem and Criteria for Guidelines," Washington, D.C. (March, 1970).

421. U.S. EPA, Working Group on Pesticides. "Proceedings of the National Working Conference on Pesticide Disposal, At National Agricultural Library, Beltsville, Maryland, June 30 and July 1, 1970," Washington, D.C.

422. U.S. Geological Survey, Water Resources Division. *Potential Contamination of the Hydrologic Environment from the Pesticide Waste Dumps in Hardeman County, Tennessee*, August 1967.

423. U.S. Government Printing Office. *Standard Industrial Classification Manual*, Government Printing Office, Washington, D.C. 20492, 1972.

424. U.S. Government Printing Office. *Water Quality Criteria 1972*, National Academy of Sciences and National Academy of Engineering, EPA-R-73-033, No. 5501-00520, March, 1973.

425. Van Valkenburg, J.W. "The Physical and Colloidal Chemical Aspects of Pesticidal Formulations Research: A Challenge," *Pesticidal Formulations Research*, Advances in Chem. Series 86, Washington, D.C. (1969).

426. Van Walkenburg, J.W. *Pesticide Formulation*, Marcel Dekker, Inc., New York, N.Y., 1973.

427. Versar Incorporated. *A Study of Pesticide Disposal In A Sewage Sludge Incinerator*, Contract No. 68-01-1587, EPA, Research and Development Office.

428. Villanueva, E.C. "Evidence of Chlorodibenzo-p-dioxin and Chlorodibenzofuran in Hexachlorobenzen," *Agricultural and Food Chemistry*, *22*(5) (Sept./Oct. 1974).

429. Wang, Lawrence K. *Environmental Engineering Glossary* (Draft), Calspan Corporation, Environmental Systems Division, Buffalo, New York 14221, 1974.

430. Wauchope, R.D. and Hague, R. "Effect of pH, Light and Temperature on Carbaryl in Aqueous Media," *Bulletin of Environmental Contamination & Toxicology*, Vol. 9, No. 5 (1973).

431. Way, M.J., Bardner, R., Van Baer, R. and Aitkenhead, P. " A Comparison of High and Low Volume Sprays for Control of the Buan Aphid, Aphis Fabae Scop. on Field Beans," *Amrn. Appl. Biol.*, 46(3), pp. 399-410.

432. Weast, R., editor. *CRC Handbook of Chemistry and Physics* 54th Edition, CRC Press, Cleveland, Ohio 44128, 1973-1974.

433. Weber, C.I., editor. "Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents," *Environmental Monitoring Series*, EPA 670/4-73-001, EPA, Cincinnati, Ohio 45268, July, 1973.

434. Weibel, S.R., *et al*. "Pesticides and Other Contaminants in Rainfall and Runoff," *J. AWWA*, *58*(8) (1966).

435. Weiss, A. and Kramich, W.L. *Catalytic Conversion of Hazardous and Toxic Chemicals*, EPA Grant R-802-857-01, January 1975.

436. Weiss, C.M. "Organic Pesticides and Water Pollution," *Public Works*, 95(12):84-87, December 1964.

437. Wershaw, R.L., *et*. *al*. "Interaction of Pesticides with Natural Organic Material," *Environmental Science and Technology*, *3*(3) (March 1969).

438. Wesvaco. *Activated Carbon and Waste Water*, Covington, Virginia 24426, 1973.

439. Wetzel, R.B. *Limnology*, W.B. Saunders & Co., Philadelphia, Pa., 1975, 743 pp.

440. Wiersma, G.B., Tai, H. "Mercury Levels in Soils of the Eastern United States," Pesticides Monitoring Journal, 7(3/4) (March 1974).

441. Wilder, I. Letter to W.L. Miller, Effluent Guidelines Division (WH552), U.S. EPA, Washington, D.C. 20460, August 20, 1976.

442. Wilhelmi, A.R., Ely, R.B. " A two-step process for toxic waste waters," Chemical Engineering, (Feb. 16, 1976).

443. Winchester, J.M., Yeo, D. "Future Development in Pesticide Chemicals and Formulations," Chemistry and Industry, 27(4) (January 1968).

444. Wincholz, M., editor. The Merck Index, ninth edition. Published by Merck & Co., Inc. Rahway, N.J., U.S.A. (1976).

445. Wolfe, N.L., et. al.. "Exposure of Mosquito Control Workers to Fenthion," Mosquito News, American Mosquito Control Assoc., Inc. (Sept. 1974).

446. Wolfe, N.L., et. al. "Captain Hydrolysis," J. Agric. Food Chem., Vol. 24, No. 5, 1976.

447. Wolfe, N.L., Zepp, R.G. and Pans, D.F. Carbarul, Propham, and Chlorpropham: A Comparison of the Rate of Biolysis, U.S. EPA, Environmental Research Laboratory, Georgia, 1977.

448. Wolfe, N.L., et. al.. "Chemical and Photochemical Transformation of Selected Pesticides in Aquatic Systems," Ecological Research Series, EPA-600/3-76-067, September 1976.

449. Wolfe, N.L. Correspondence with ESE. Data provided through EPA Washington Office, July 1, 1977.

450. Wolfe, N.L. "Hydrolysis of Atrazine," inter-office memo to L. Miller, U.S. EPA, August 13, 1976.

451. Wolfe, N.L, et. al. Methoxychlor and DDT Degradation in Water: Rates and Products, U.S. EPA Environmental Research Laboratory, Athens, Georgia, Nov. 9, 1976.

452. Wolfe, Lee N., et. al. "N-Nitrosomine Formation from Atrazine," for EPA, Bulletin of Environmental

Contamination and Toxicology, Vol. 15, No. 3, 1976, p. 342.

453. Wolfe, N.L., Zepp, R.G. and Paris, D.F. Use of Structure--Reactivity Relationships to EStimate Hydrolytic Persistence of Carbamate Pesticides, U.S. EPA, Environmental Research Laboratory, College Station Rd., Athens, Georgia 30601, 1976.

454. Woodland, R.G., et. al. "Process for Disposal of Chlorinated Organic Residues," Journal of the Air Pollution Control Assoc., 15 (2) (Feb. 1965).

455. WPCF, APHA, AWWA. "Standard Methods for the Examination of Water and Wastewater," 14th edition, 1975.

456. Yader, J., et. al. "Lymphocyte Chromosome Analysis of Agricultural Workers during Extensive Occupational Exposure to Pesticides," Mutation Research, Vol. 21, Elsevier Scientific Publishing Company, Amsterdam, 1973.

457. Young, David R., et. al. "DDT in Sediments and Organisms Around Southern California Outfalls," Journal Water Pollution Control Federation, Vol. 48, No. 8, August, 1976.

458. Yost, J.F., Frederick, J.B. and Migrdichian, V. "Malathion and Its Formulations," Agricultural Chemicals, September 1955.

459. Yost, J.F., Frederick, J.B. and Migrdichian V. "Malathion Formulations," Agricultural Chemicals, October 1955.

460. Zepp, R.G., Wolfe, N.L., Gordon, J.A. and Baughman, G.L. "Dynamics of 2,4-D Esters in Surface Waters, Hydrolysis, Photolysis, and Vaporization," Envi. Sci. & Tech., 9(13):1144-1150 (1975).

461. Zindahl, R.L., Freed, V.H., Montgomery, M.L. and Furtick, W.R. "The Degradation of Triazine and Uracil Herbicides in Soil," Weed Res. 10, pp. 18-26 (1970).

462. Zewig, G., editor. Analytical Methods for Pesticides, Plant Growth Regulations, and Food Additives, Vol. II, Insecticides, Vol. III, Fungicides, Nematocides and Soil Fumigants, Rodenticides and Food and Feed Additives, and Vol. IV, Herbicides, Academic Press, New York (1964).

SECTION XIII

GLOSSARY

Act. The Federal Water Pollution Control Act Amendments of 1972, Public Law 92-500.

Active Ingredient. The ingredient of a pesticide which is intended to prevent, destroy, repell, or mitigate any pest. The active ingredients may make up only a small percentage of the final product which also consists of binders, fillers, diluents, etc.

BAT Effluent Limitations. Limitations for point sources, other than publicly owned treatment works, which are based on the application of the Best Available Technology Economically Achievable. These limitations must be achieved by July 1, 1983.

BPT Effluent Limitations. Limitations for point sources, other than publicly owned treatment works, which are based on the application of the Best Practicable Control Technology Currently Available. These limitations must be achieved by July 1, 1977.

Contact Process Wastewaters. These are process-generated waste waters which have come in direct or indirect contact with the reactants used in the process. These include such streams as contact cooling water, filtrates, centrates, wash waters, etc.

Dust. Dry, solid powder. When applied to pesticide production implies a dry, powder form product.

Formulating. A segment of the Pesticide industry which does not manufacture pesticides but mixes and blends active ingredients with binders, fillers, and diluents to produce the final product for distribution.

Hydrolysis. The degradation of pesticide active ingredients, most commonly through the application of heat at either acid or alkaline conditions.

Metallo-Organic Pesticides. A class of organic pesticides containing one or more metal or metalloid atoms in the structure.

Navigable Waters. Includes all navigable waters of the United States; tributaries of navigable waters; interstate waters; intrastate lakes, rivers and streams which are utilized by interstate travellers for recreational or other purposes;

Preceding page blank

intrastate lakes, rivers and streams from which fish or shellfish are taken and sold in interstate commerce; and intrastate lakes, rivers and streams which are utilized for industrial purposes by industries in interstate commerce.

Non-contact Cooling Water. Water used for cooling that does not come into direct contact with any raw material, intermediate product, waste product or finished product.

Noncontact Wastewater. Wastewater which does not come in direct contact with process materials.

NPDES. National Pollution Discharge Elimination System. A federal program requiring industry to obtain permits to discharge plant effluents to the nation's water courses.

Organic Pesticides. Carbon-containing substances used as pesticides, excluding metallo-organic compounds.

Organo-Nitrogen Pesticides. Pesticides which use nitrogenous compounds as the active ingredients.

Organo-Phosphorus Pesticides. Pesticides which use phosphate or phosphorus compounds as the active ingredients.

Packaging. The last step in preparing a pesticide for distribution to the consumer. This segment of the industry takes the final formulated product and puts it into a marketable container such as drums, bottles, aerosol cans, bags, etc.

Pesticides. (1) Any substance or mixture of substances produced for preventing, destroying or repelling, any animal or plant pest. (2) General term describing chemical agents which are used to destory pests. Pesticides includes herbicides, insecticides, fungicides, etc., and each type of pesticide is normally specific to the pest species it is meant to control.

Pesticides Chemicals. The sum of all active ingredients manufactured at each facility.

Pretreatment. Any waste water treatment process used to partially reduce the pollution load before the waste water is introduced into a main sewer system or delivered to a treatment plant for substantial reduction of the pollution load.

Process Wastewater. Any water which, during manufacturing or processing, comes into direct contact with or results from the production or use of any raw material, intermediate product, finished product, by-product, or waste product.

Volatile Suspended Solids (VSS). The quantity of suspended solids lost after the ignition of total suspended solids.

SECTION XIV

ABBREVIATIONS AND SYMBOLS

API	American Petroleum Institute
BOD_5	biochemical oxygen demand, five day
Btu	British thermal unit
°C	degrees Centigrade
cal	calorie
cc	cubic centimeter
cm	centimeter
COD	chemical oxygen demand
°F	degrees Fahrenheit
F/M	BOD (kg/day)/kg MLVSS in aeration basins
fpm	feet per minute
fps	feet per second
ft	feet
gal	gallon
gpd	gallon per day
gpm	gallon per minute
hp	horsepower
hr	hour
in	inch
kg	kilogram
kkg	1000 kilograms
kw	kilowatt
L(l)	liter
lb	pound
m	meter
M	thousand
mg	milligram
mgd	million gallons daily
min	minute
ml	milliliter
MLSS	mixed-liquor suspended solids
MLVSS	mixed-liquor volatile suspended solids
mm	millimeter
MM	million
POTW	public owned treatment works
psi	pound per square inch
rpm	revolution per minute
sec	second
S.I.C.	Standard Industrial Classification
sq.ft.	square foot
TDS	total dissolved solids
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
TOD	total oxygen demand
TSS	total suspended solids
ug	microgram

Preceding page blank

TABLE XIV-1

METRIC TABLE

CONVERSION TABLE

MULTIPLY (ENGLISH UNITS) by TO OBTAIN (METRIC UNITS)

ENGLISH UNIT	ABBREVIATION	CONVERSION	ABBREVIATION	METRIC UNIT
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram - calories
British Thermal Unit/pound	BTU/lb	0.555	kg cal/kg	kilogram calories/kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	°F	0.555(°F-32)*	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liters
gallon/minute	gpm	0.0631	l/sec	liters/second
horsepower	hp	0.7457	kw	killowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig +1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
ton (short)	ton	0.907	kkg	metric ton (1000 kilograms)
yard	yd	0.9144	m	meter

* Actual conversion, not a multiplier